Community Assistantship Program

C-G-B School Greenhouse

Prepared in partnership with
Big Stone Area Local Foods Group

Prepared by
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University of Minnesota
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Design for Community Resilience
Center for Sustainable Building Research
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University of Minnesota
16 August, 2010

C-G-B SCHOOL GREENHOUSE

Dear Members of the C-G-B School Board and C-G-B community,

The following document is a summary of our in-process research related to the C-G-B Greenhouse project so far. We look forward to your feedback and any suggestions that we may consider for the remainder of the project.

In this document we discuss; the case studies we reviewed or visited, aspects of greenhouse design, and the best emerging design options from the energy modeling conducted for the project. The document includes the final scheme proposed for the project. Based on feedback and research in the final phase, the final document will be sent to you on August 29th 2010.

Thank you,

Research Team

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GOALS

OVERALL:
-CONNECT STUDENTS TO THE WHOLE CYCLE OF FOOD

SPECIFIC
The Goals of the greenhouse include:

1-Operating cost be as low as possible

2-Greenhouse be producing for the school lunch program

3-Greenhouse be attached to science classroom

INTRODUCTION

What is the C-G-B School Greenhouse Project?

The C-G-B School Greenhouse Project aims to install a greenhouse attached to the C-G-B School in Graceville, MN. It continues a successful ongoing effort of the past two gardening seasons where students have been involved in a community-school garden. The students raise vegetables under guidance of community members and teachers for the senior-citizen meal programs in town - 136 youth in 2008 and 150 in 2009 raised two dozen different kinds of vegetables in amounts sufficient to provide a meal for at least 30 senior citizens at a time.

In addition, Big Stone Area Local Foods group has been meeting for nearly 2 years and builds upon a local community planning effort called Creating a Value Added Community. In 2010 the group is completing a local foods assessment that has identified Farm to School as among the top priorities.

What are the goals of the project?

On December 14, 2009, the Board of C-G-B School approved research into the feasibility of a greenhouse at C-G-B School with the following direction:

- the greenhouse be attached to the school, to make it more integral to the school program
- it be at the Middle and High School in Graceville rather than at the Elementary School in Clinton, on the premise that the older students can learn more from and contribute more to a greenhouse
- the produce from the greenhouse be used in the school lunch program
- the educational use of the greenhouse be primarily in the science classes
- the capital costs come from grants and donations, and
- the operating costs incurred by the district be minimum.

What research topics are driving the project?

The specific research questions of this project are:

1. Siting – where could the greenhouse best be attached to the present building?
   Where might a work and storage area adjacent to the greenhouse be located?
2. Sizing – how large a greenhouse would be needed? To provide produce for a school lunch program serving c. 170 meals accommodating perhaps 25 students in a class at a time?
3. Lighting – would supplemental lighting make sense?
4. Heating – what would it take to maintain throughout the winter a minimum temperature of 50 degrees F? Of 60 degrees F? This involves questions of:
   Construction materials – glazing, insulation, nightshades, doors.
   - o The frame will have to accommodate high moisture.
   - o Glazing involves a number of considerations:
     - Light transmission
     - Energy efficiency
     - Life span
     - Special treatments, such as anti-static to prevent dust or moisture condensation.
     - Safety
     - Hail resistance

   Solar heating strategies
   Supplemental heating options
5. Venting – both for cooling and for the necessary air circulation
6. Supplying water and electricity

What is the relevance of this project for the larger community?

The community sees this project as a way of moving ahead with its goals around feeding local children healthy food and installing the self-confidence and experience of producing food. So far there are no identified production greenhouses at any elementary, middle or high school in Minnesota, although there are a few teaching greenhouses.

What is the final outcome of the project intended to be?

The final product will be a written report, which should include preliminary building specs, schematic design, and drawings as well as preliminary cost estimates for both construction and operation and recommendations for next steps. The intention is to have documents with which the community can hire other consultants as needed to further design and build the project.

What are the projects implementation funding prospects?

A major part of the community's fund-raising strategy is to develop the C-G-B Foundation, which was founded by two members of the community. This Foundation, under the Southwest Initiative Foundation founded by the McKnight Foundation, exists for the purpose of enriching the educational experience of C-G-B students but it needs to be developed. The community intends to create a donor list, which would be primarily of C-G-B alumni, and to produce public relations materials, like a brochure, to use in soliciting funds from individuals for the Foundation, including for the greenhouse.

GRACEVILLE, MN

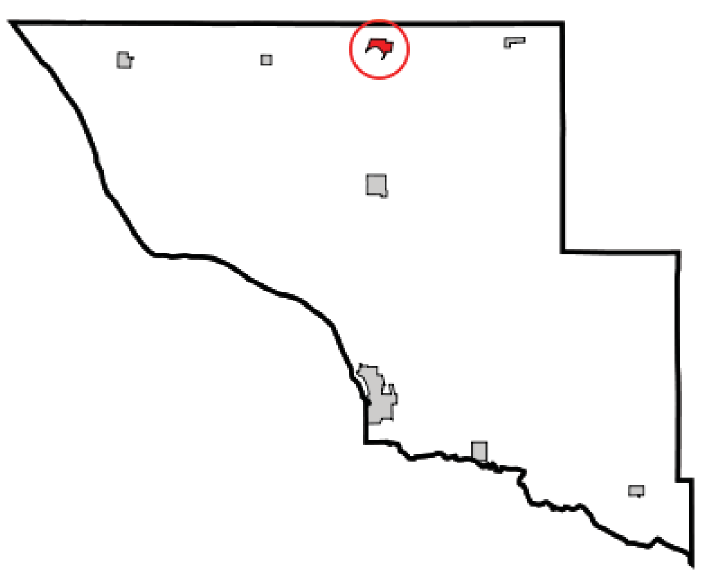
GRACEVILLE, MN

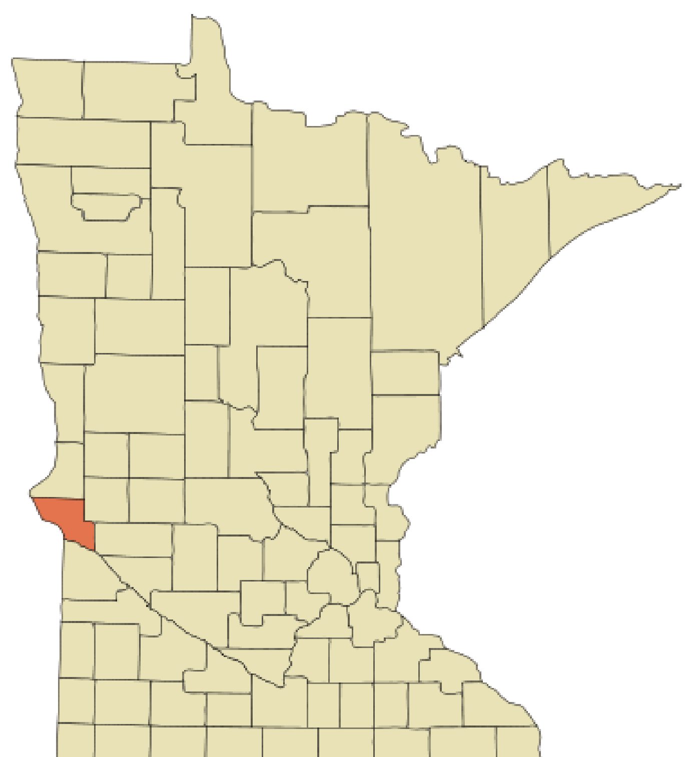
Big Stone County
population: 605 in 2000

total area of 0.6 miles
located on the northeast corner of Toqua Lake

In a natural area called a wet prarie, which is a mix of prairie land, sqamp and numerous small lakes and ponds.

A large wind farm is in development east of town





Aerial of Graceville, MN

Local restuarant

Original fire station converted into a house

C-G-B SCHOOL

South facade of school

Equipment room

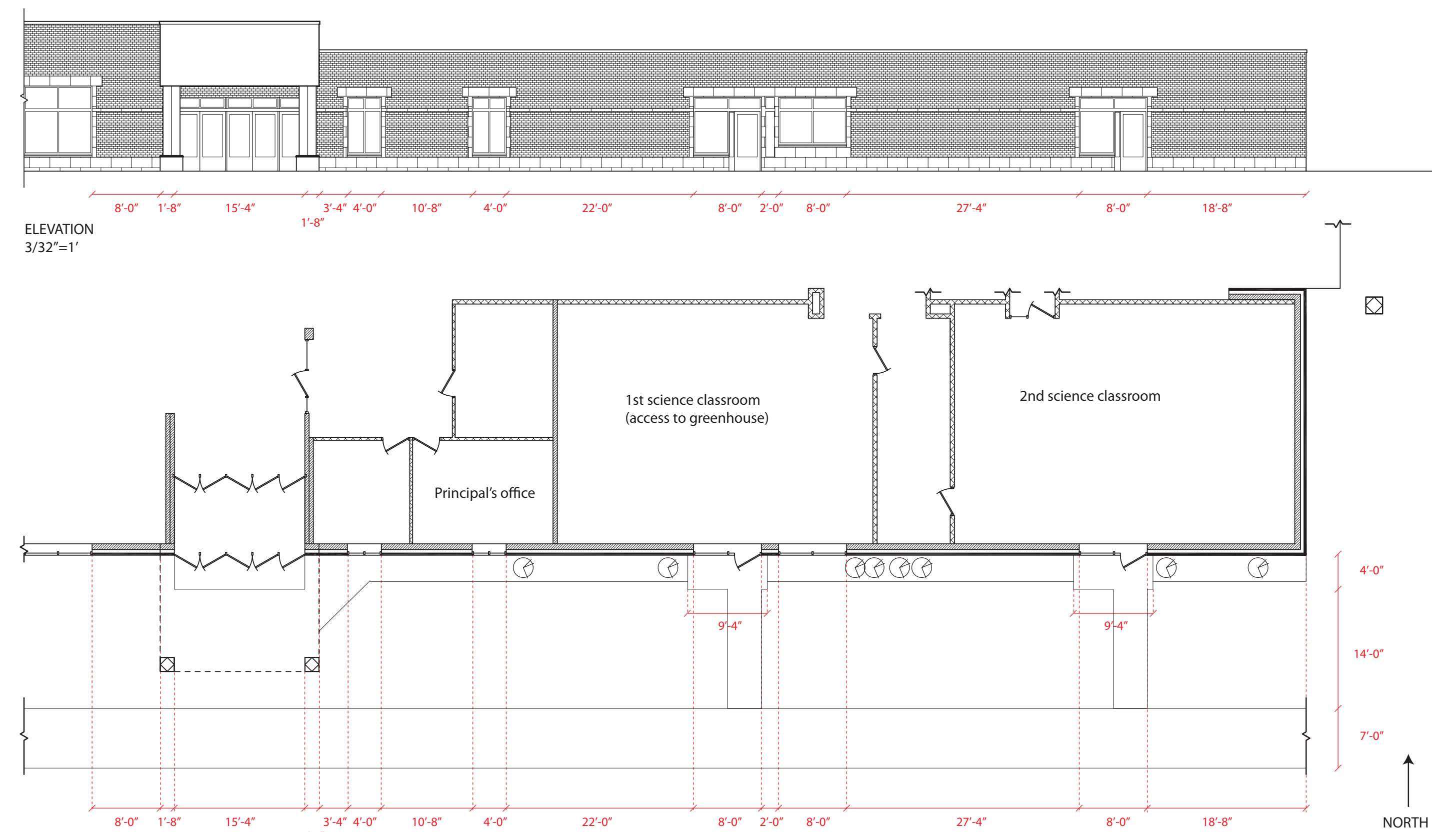
"Wolverines" mascot

Open dining room

Community garden compost tumbler

Community garden is located in an infill lot in the neighborhood adjacent to the school.

Rows of vegetables



CASE STUDIES/ RESOURCES

MINNESOTA:

UNIVERSITY OF MN ST. PAUL
-contact John Erwin

WILLMAR: (3 hrs east of msp)
-run by high school students (only a handful called "YES")
contact: Rob Palmer
-estimates water, gas and electric are costing about $2,000/yr (same cost for biomass furnace)
-an attached greenhouse would be more heat efficient
-greenhouse 1 mile off campus
-grow: greens, carrots, beets, kohlrabi
-no pest problems only disintegrating water pipes
-most of produce goes to local food shelf and some to school
-don't have the volume or steady flow to go to school
-only using half (east half) no auxilliary lighting in east half (flourescent in west)
-east half heated by water heated in the solar collectors banked along the ground about 20 ft south of the greenhouse (piping in floor)
-biomass heater as backup
-excellent venting; bank of window along entire top of greenhouse open automatically (thermostatically controlled)
-get compost free from the city composting facility

DAKOTA RIDGE SPECIAL EDUCATION SCHOOL(Apple Valley)
-contact:Jeremy Illg
-very small greenhouse attaced, main greenhouse stand alone
-30'by 30'
-starts all plnatsfrom seeds
-butterfly garden, what plants attract how many and what kind of butterflies
-aims for night temp of 75 and day temp of 71 degrees
-waters with overhead sprinkling system
-plants tired three deep, difficult for watering and sunlight
-producing bedding plants and flowers
-does not operate through winter
-uses a "proportioner" in the irrigating system which mixes water and fertilizer

CHAMPLIN PARK HIGH SCHOOL (by Anoka)
-contact: Dan Foss
-stand alone and 1,800 sq ft (40' x 45'
-constructed 12 yeras ago for $160,000
-totally computerized as the computer controls the vents, two furnaces , the shade cloth and the automated water sprinklers
-plant sale annually, usually make $12,000 from sale (10th year of sale)
-most plants started from seedlings
-one of the largest schools in the state
-producing bedding plants and flowers
-operates through the winter keeping it at 60-65 degrees
-sodium vapor lights used for supplemental lighting are expensive and have been obtained through the police department drug busts
-landscape piece connected to greenhouse
-use pesticides in the greenhouse
-keep temp warmer at night than day as it has some beneficial effect on plant growth (reverse differential)
-attempt to produce plants that are not so tall and leggy but shorter, stockier and stronger
-use germination mats

PARK HIGH SCHOOL(Cottage Grove) (30 min S)
-1850 students
-contact: Jean Wagner
-attached directly to the science classroom
-30' by 60'

GEOTHERMAL GREENHOUSE (Winona County)
Whitewater Gardens
17485 Calico Hill Rd.
Altura, MN
-packing building and greenhouse 20' apart
-geothermal systems measured by ton (amount of heat/ BTUs it takes to change one ton of ice at 32 degrees F to water at 32 degrees F
　-loop here is 20 tons
　-coils buried only 14" deep, a worry when using rototiller
-keep temp between 55 and 60 at night and not over 70 during day
-ventilation is doors and peak ventlation, two fans at top to drive heat down
-problem with humidity, gets to 90% at night, down to 30% during the day
-rule of thumb (change air in greenhouse four times every hour)
-coils in the soil keep soil at 72 degrees at 12" deep, it is 63 degrees at the surface
-one whole side devoted to tomatoes, also cucumbers, spinach

Three kinds of geothermal systems:
　-pump and dump (cheapest but can only be installed in sandy soil where dumped water will circulate back into the natural water flow)
　2-a well, usually about 200' deep
　3-horizontal slinky, rub pipies latterly underground
*cost of 1200 sq ft greenhouse , takes 32-33 BTUs per sq ft and would need about a 4 ton system $30,000
KEVIN(midvalley@arvig.net)
1847 1st Ave in Reynolds, ND.
*go to Econar website for geothermal systems
-greenhouse is 50; by 120;

WISCONSIN:

HOWARDS GROVE (Sheboygan)
-across small parking lot from school
-50'x30'
-had chickens in an enclure at far end
-mostly bedding plants and flowers
0glazing double tick polycarbonate
-number of louvered vents
-large heating unit hanging from ceiling

PLYMOUTH (Sheboygan)
-two greenhouses (stand alone hoop house and one attached to cement block building)
-glazing on hoop house quite opaque, chickens
-

NORTH HIGH (Sheboygan)
-contact: Paul Reinemann science teacher)
-operates throughout school year
-attached directly to classroom
-faces directly south, running along entrance side of the building
-about 65'
-glazing polycarbonate
-ductwork running inside blocks much of light
-has its own furnace, fired by gas from the school's heating system
-68 to 85 degrees
-entrance from classroom
-uses for botany and biology classes: growth hormones
-all plants are in containers, permanent beds would be a mistake as they would be difficult to had soil problems
-sticky pads throughout greenhouse to catch pests
-needs to earn money from sale of bedding plants, flowers and transplants they sell in spring (uses to buy supplies for next year)
-costs around $2,000
　$1300 FOR PLUGS TO START FLOWERS AND BEDDING PLANTS
　$50 for seeds (tomatos etc)
　$375 for soil
-only vegetables were three roma tomato plants
-tables made from 2x4s and heavy wire mesh

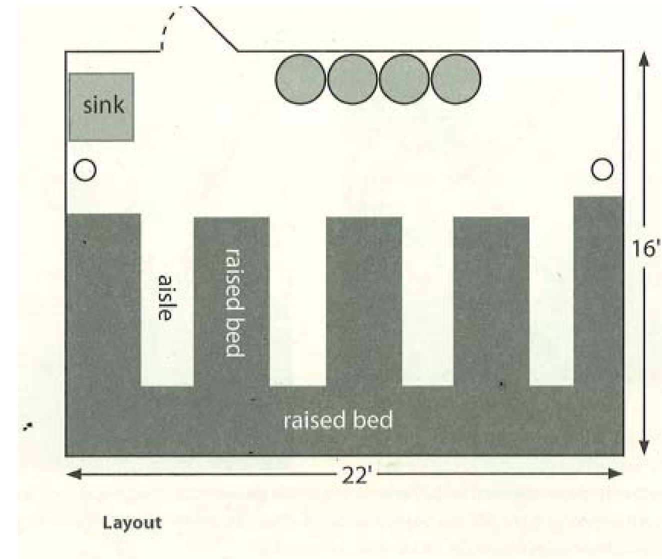
DURAND
-575 students in 7-12th grades
-20' by 60'
-polycarbonate glazing
-sued for plant science and horticulture classes
-use supplemental lighting, set to timer for 14 hrs of light/day
-minimum temp in 70 deegrees, start venting at 71 degrees
-operates throughout school year
-producing some vegetables for school's lunch program
-some hydroponically grown plants in two separate systems (lettuce)
-one system runs off fish tank, using fish waste and some added nitrogen is enough
-grow: tomatoes, cucumbers, rhubarb chard and peppers,
-only pest problems are spider mites and white flies (managed with soapy sprays)
-no root crops yet, thinking of digging permanent bed on far end and doing carrots and beets
-pollination caused from breeze and kids rustling the plants
-biggest cost is containers

OTHER GREENHOUSES: NON-SCHOOL

Norm Erickson
Hazelnut Farm and Passive Solar Greenhouse
Lake City, MN
-creating an energy source on the landscape (Hazelnuts as biofuel)
-seasonal thermal energy storage goal to operate 8+months a year without any external energy source except power for ventilation fans

CASE STUDY 1
MILAN GREENHOUSE

"...the states food system is deeply dependent on a most vulnerable resource: oil. Our willingness to ship food long distances, our ability to send large tractors and combines into the fields, and the logistics of importing over half of the fertilizer used on our massive grain fields-all of this boils down to assuming that oil will be (1) available and (2) cheap. As oil supplies peak, both assumptions are breaking down. " foreward xiii
The Northlands Winter Greenhouse Manual: A unique, low-tech solution to vegetable production in cold climates



GENERAL INFO
_Winter CSA (provide greens to 20 families)
_Used Eliot Coleman's book about four-season gardening strategy –not quite appropriate to Midwestern winters
-Chuck Waibel and Carol Ford
_Attached to their garage
_temp in upper 40s (spending less than $100/yr for heat)
-built for $12,000 (2/3 was labor cost)
-11 CSA memebrs, gross from CSA is $5,000-6,000/yr
_mostly just greens (having a hard time growing spinach)
_8 hrs/wk in greenhouse (packing once a week)
_would have added more vents (difficult to kep temp down on sunny days in spring and fall)
_some "thermal curtaining" might help as well to retain heat on cold winter nights
_written a book

DESIGN NOTES
"Keyhole" or peninsular design with perimeter raised bed

Beds are not subject to the usual problems of soil compaction, each fall add another round of 1-2 inches of basic soil mix
Do not seed on the raised beds for two reasons
_plants germinate and begin their lives more vigorously if started on heat, like on a propagation mat
_space is precious and don't want bare spots where germination failed for one reason or another

GREENS
_takes 3-5 cuttings before soil is spent and must be replaced
_can this be mitigated by using fertilizer?
_clean rain gutter planters out with bleach water (1 tsp of bleach per gallon water)
_fill clean planters to the top with dry soil mix and lightly press down with hands, then water thoroughly to moisten the mixture

HEATING MATS
_mats act like big heating pads, help seeds sprout more quickly because they warm the soil from below. _once seedlings have sprouted and start their first true set of leaves, they come off heat

WATERING
_greens are watered daily, feel soil to see if water is needed
_use an extendable watering wand

TIMING
_does it matter what time of year everything is happening, what is the concept of seasons in a temperature controlled greenhouse?
_is it only greens grown in the hanging planters? How deep?
_DIMINISHING, SOLSTICE and EXPANSION periods of growth

CASE STUDY 2

CHISAGO AREA GREENHOUSES

North Branch High School
North Branch, Chisago MN

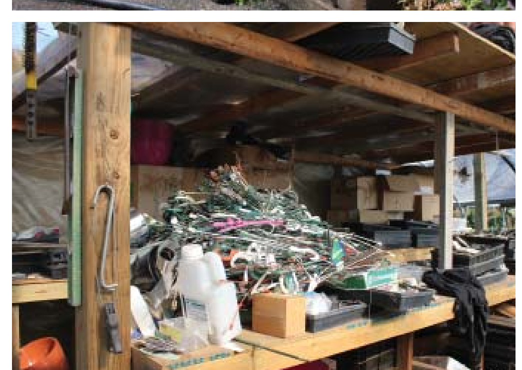
Waynes Nursery and Greenhouse Garden Center
Stacy, MN

Sunrise Native Plantings
Chisago, MN

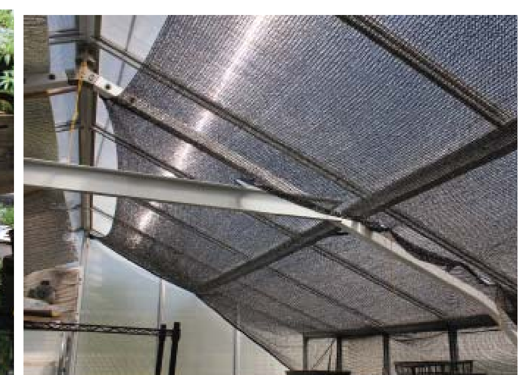
LAYOUT

_Parts of the commercial greenhouses were used year round (plants were moved from place to place
_The interior greenhouse environment was modified though the seasons by adding and removing layers of plastic poly greenhouse sheeting, this allows for microclimates in spaces between the interior and exterior
_Heat retained with strawbales and air spaces between plastic sheeting
_Dirt floor, all plants were water with hand spraying
_Heated with wood furnace

TABLES



HEATING/COOLING



CASE STUDY 3
PARK HIGH GREENHOUSE

Park High School
Cottage Grove, MN

Albert Lauer Mock Greenhouse
Cottage Grove, MN

VENTILATION

STRUCTURE

CASE STUDY 4
ALBERT LAUER

Waupaca Middle School, WI
constructed by Albert Lauer Greenhouse Manufacturers

Albert Lauer is the greenhouse manufacturer we have identified as being appropriate for this project's scale and requirements. They have done many attached greenhouses on schools in Wisconsin which serve as examples for this project.

DESIGN ASPECTS

1_ORIENTATION/SUN ANGLE

SEASONAL SUN ANGLES

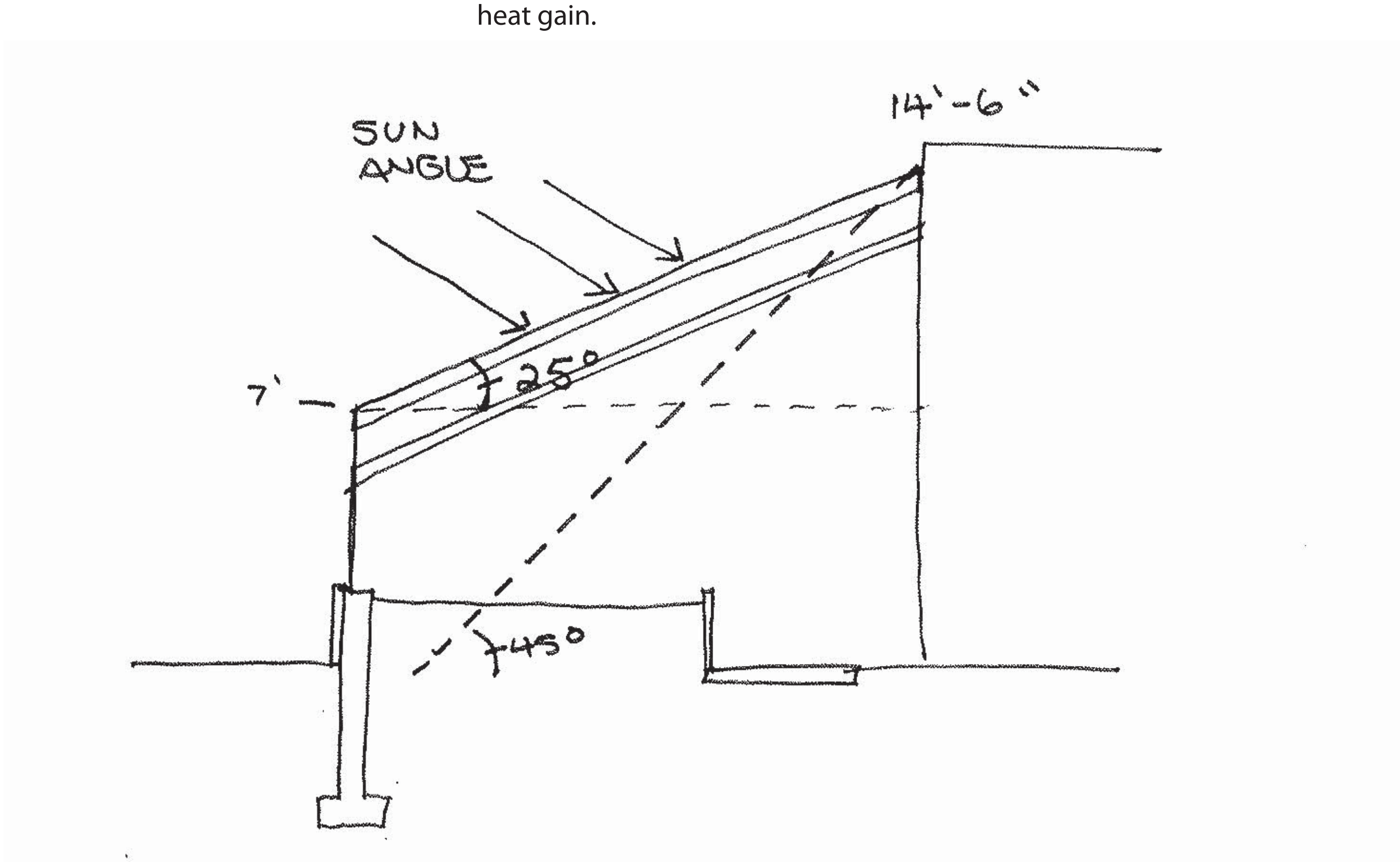
-when capturing sunlight for heat, the angle at which the light hits your glazing influences how much light you capture and how much is just reflected. You want this solar incidence angle to be as close as possible to straight out from your glazing at the time o the year when you most need it (dec 21)
-ideal figure is 68.5 degrees

March 21-45 degrees
Sept 21-45
Dec 21-21
June-68

-any angle within 25 degrees of ideal will still get you 90 percent of the incoming solar energy

The Graceville greenhouse is restricted by the space available in front of the school. To maximize growing space the greenhouse extends in front of the school 16 feet. The top of the school wall is 14.5 feet. Futhermore, ADA wheelchair accessibility requires that there be enough headroom up to the edge of the greenhouse. Because of this, the south edge of the greenhouse is 7' (with structure hanging below 2'), and the resulting angle is 25 degrees to the top.

Though this is less than ideal, it will still serve to capture a large quantity of solar heat gain.



2_LOADS

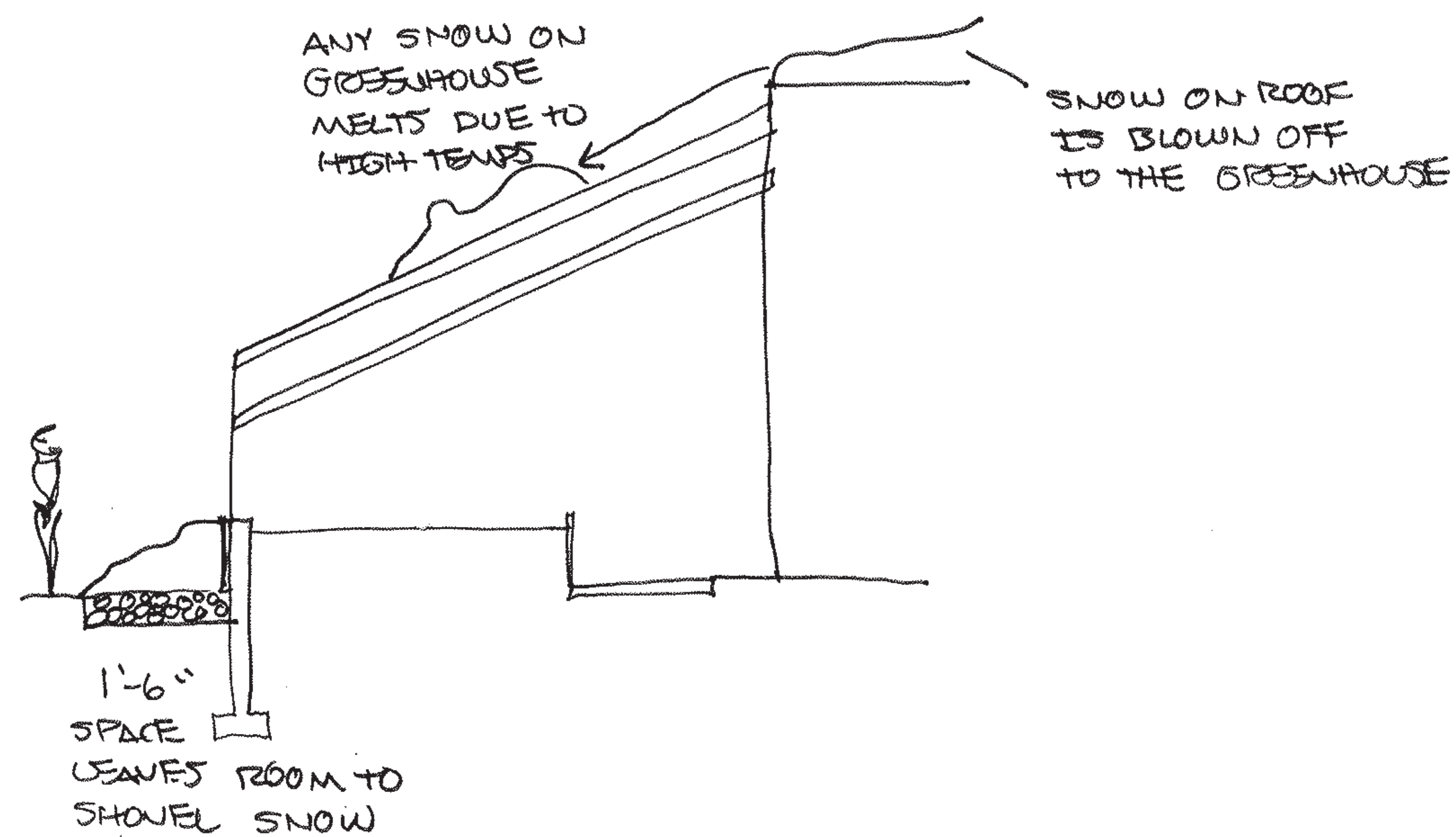
SNOWLOAD:
_40 lbs of snowload
_wind from NW piles snow on edge of building

RECOMMENDATIONS:

While angling the greenhouse roof down immediately from the edge of the exisiting roof would facilitate snow removal, snow would be allowed to enter the greenhouse through necessary roof vents. The only snow load that would be a concern was that which stayed trapped behind the greenhouse.

There would not be an issue of snow piling up on the greenhouse because any snow landing on top of the greenhouse would be melted easily by the high temperature of heat escaping through the paneling.

Angling the greenhouse first up from the roof of the exisiting school and then down towards the sidewalk will allow enough clearance so that vents can still be opened in the winter without snow getting inside. If, in the event that a large quantity of snow piles up behind the greenhouse peak, the north vent could be closed to seal the greenhouse, and the south vent would still be in operation.



3_SOIL

-use soil-based or soilless mixes that have been heat sterilized so they contain no living organisms
-use commercial soilless mix for starting seedlights

PH
-keep between 6.0-6.8
-add mineral amendments (bone meal) to provide additional nutrients

-when filling beds, first lay down a few inches of gravel and few inches of sand on bottom for drainage, then add 1 1/2 feet of mix

NUTRIENTS:
-macro-nutrients: nitrogen, phosphorus, potassium
-micro-nutrients: iron, sulfur and zinc
-commercial liquid or water-souble fertilizers, or slow-release pellets
-require more nutrients during summer when they recieve more light and heat, and fewer in winter

STARTING WITH SEEDS:
-plant seeds at a depth of two to three times their width
-plant seeds that are very fine, or require light, by sprinkling them on the surgace and gently patting them into the soil
-put two seeds in each planting hole
-keep soilless mix moist while seed are germinating by covering container gently with a plastic bag or dome
-keep containers in a warm spot (70-75%) or use heating mats
-once seedlights emerge, put them in the light, keep lights 1-3 inches from seedilings
-fertilize the seedlings once six to eight leaves have emerged

STARTING FROM CUTTINGS:
-depending on plant you can take stem, leaf, or plantlet cuttings
Stem cuttings: begonia, coleus, geranium, impatiens, ivy, philodendron tomato, wandering jew

RAISED BEDS MIX

7 buckets of peat
1 cup garden lime
2 cups blood meal
2 cups green sand
2 cups rock phosphate
1 40 lb bag of compost

PLANTERS AND SOIL BLOCKS

3 buckets of peat
½ cup of lime
2 buckets of vermiculite
1 cup of greensand
1 cup rock phosphate
1 cup blood meal
3 buckets of compost

*1 bucket =1 gallon

4_SOIL COMPONENTS

peat moss

Peat Moss
_when you use this product in your soil mix, you need to add some lime to offset the acidic nature of peat
_provides humus, retains moisture and creates the air space roots need
_comes in bales at most home and garden store, avoid sticks and stems

vermiculite

Vermiculite
_super heated rock that expands into a flaky material
_keeps soil mix fluffy, helps retain moisture and adds some trace micronutrients
_perlite is an alternative, does not absorb moisture or have any nutrition

compost

Compost
_contains nutrients and organisms beneficial to your plants
_vermicompost is superior to plain compost because the nutrients in organic material that has passed through a worm's digestive system are more readily available to plants

Organic Fertilizer
_equal parts greensand, rock phosphate, and blood meal

greensand, rock phosphate and blood meal

Greensand (glauconite)
_a mineral deposit formed on ancient ocean floors.
_supplies potassium (which help s in plant metabolism building protein, photo-synthesizing, fighting off disease)
_silica, iron oxide, magneasia, lime, phosphoric acid
_looks like very fine sand of sage green color

Rock Phosphate
_provides phosphorus-essential to photosynthesis
_aids in the formation of oils, sugars and starches

Blood Meal
_nitrogen component of the fertilizer mix

5_AESTHETICS

The proposed greenhouse will be placed on the south side of the school, which is also the front of the building, thus having desire to match the exterior of the building. Ideas included coloring of mullions to match blue rain gutters and carrying the CMU rock face along the 24"high knee-wall.

RECOMMENDATIONS:
The manufacturing process of having colored mullions would require the entire greenhouse be built off site first to be colored at the manufacturer's warehouse (Albert Lauer) and then disassembled and reassembaled on site. This process would add an estimated 15% to the cost. Our recommendation is that matching the building aesthetically in other ways would be more cost-beneficial.

The height of the decorative CMU wall is 24", which matches well with our desired raised bed height. Carrying a matching CMU block around the greenhouse will help it look less "added on" and more integrated with the facade.

6_CODES

EXIT DOORS:
_Two exit doors are necessary, and the entrys must remain open at all times

FIRE HYDRANT:
_There is no requirment for distance from the fire hydrant, remaining 20 feet away is a safe distance.

SPRINKLER SYSTEM:
_There must be a sprinkler system installed in the greenhouse

WHEEL CHAIR ACCESSABILITY:
_42" paths throughout the greenhouse are necessary for wheel chair accessable corridors.

RECOMMENDATIONS:

All aisles within the greenhouse should be 42" wide to allow for wheel-chair accessability.

Exit door areas should remain unobstructed, and an exit-only door on each end of the greenhouse is required to maintain exit-door code compliance.

While there is no direct requirement regarding the distance from the fire-hydrant, the greenhouse should not come within 20' of the hydrant.

A sprinkler system must be installed within the greenhouse because it is classified as an attached room to the school building.

7_GLAZING


opaque system of structural panels

CRITERIA
_light transmission and energy efficiency
_life span
_special treatments (heat trapping, antistatic, prevents condensation, diffuse light)
_saftey and durability (hail resistence)

GLASS
_glass has highest operating costs, but most structural stable
_highest direct light infiltration, may cause extremely dark and light spaces because light is not diffused


opaque system of structural panels

RECOMMENDED: ACRYLIC
_4' Acrylic panels recommended (16mm)
_poly-carbonate panels cheaper but more flimsy
_less heat loss than glass
_4' modules, but can be cut


opaque system of structural panels

POLYCARBONATE GLAZING
-polycarbonate sheets 4x12' sheets, takes 7-10 yrs to yellow_Polycarbonate wen light passes through a clear substance into a room, then bounces around, its wavelength changes, meaning that it becomes heat. Polycarbonate is very good at keeping this "changed light" from escaping. It also diffuses light, getting rid of very bright and very shady areas found in a space that uses a clear covering like untreated glass.


opaque system of structural panels

POLYCARBONATE SHEETING
_cheapest option
_has no structural properties
_can be clear or diffuse light with slightly opaque sheets
_comes in 16 wide foot rolls
_can be layered with an air space or straw/hay for extra insulation

8_SEED GERMINATION

Seed germination times vary from 5 days to 2 weeks or longer. Generally greens take 10-14 days, while vegetables take only 5-8 days.

A soil blocker is a handy and inexpensive tool for planting seedlings without having to use many plastic germination trays. It is similar to a cookie cutter. When pressed into the soil it creates 4 soil blocks at a time with a dimple for placing the seeds.

FLATS
_typically 11 by 21 inches and a few inches deep
_50 soil blocks fit in one tray
_water from the side and allow water to fill in the bottom of the tray
_blocks are beneficial for air and space, there is air between the blocks which acts as a barrier to growing roots, root bound transplants are easily stressed because roots are so exposed to dryness and heat, roots should be poised and ready to shoot to into the transplanted soil
_soil blocks have over three times as much soil to grow in as one in a typical transplant cell, and reduce plastic use
_gently push the soil down to the seed has contact with soil and moisture
_gently cut the seedlings that are extras in each block at soil level

9_HUMIDITY

IDEAL HUMIDITY: between 45-60 percent

_high humidity leads to pest and disease probelms
_low humidity can dry out plants

Excess water on plant leaves can cause fungus and disease on plants. This can be caused by too humid conditions or watering from above. This can be eliminated by watching humidity carefully and watering with irrigation tubes and from below with trays.


heating unit


wood fired stove

10_HEATING/TEMPERATURE

-Virtual Grower software helps determine temp differences min of 50 degrees vs 60 degrees
-cool weather crops (lettuces, spinach, sugar-snap peas) would do fine at 50 degrees min.
-would like to grow warm-weather crops (cucmbers and tomatoes) min temp of 63 degrees
MIN
50-60 degrees
MAX 85 degrees
-plants do best with a 10-15 degree drop between day and night temps
-plants native to temperate climates or with edible leaves or roots prefer cooler temps
-tropical natives or food plants that produce edible fruits (tomatoes) withstand higer temps

COOLING:
-commercial shadecloth (made of spun or mesh vinyls)
-applying water soluble sahding compounds to glazing during late spring

SOIL:
-when soil temp is below 45 F roots grow more slowly and are less efficient at taking up water
-65-75 is recommended for germinating most types of seeds

SOLAR HEATING
-north wall made of dark, heat absorbing material such as stone or black barrels filled with water
-raised soil-filled beds also contribute to heat storage
-east and west walls are often half-solid
-southern side fully glazed, angled so the sun's rays hit it perpendicularly during seasons of maximum greenhouse use
-two layers of glazing with an air space between to insulate and reduce heat loss at night

HEATING:
_heating system is better along walls than hanging because it doesn't block light

11_WATER

flooding irration system fills bottom of tray

-factors: drainage capacity of growing medium, temperature and light plants receive, amount of air circulation, stage of plant growth, type of plant.
-if soil feels dry an ich down, its time to water
-use slightly warm (65-80 water)
-water in morning to minimize evening condensation on leaves, which can encourage diseases
-minimize watering on cool, cloudy days
-be sure to water thouroughly, watering to lightly can cause a buildup of fertilizers alts which stimulates shallow, surface roots

12_SOLARIZATION/STERILIZATION

fertilizer pumped into the irrigation system

"cooking" a greenhouse, using sunlight to kill plant and animal pests

_120 degrees for 4 weeks

The conventional way to kill off bacteria and pests in greenhouse environments and soil is to heat up the soil to 180 degrees and keep it at that temperature for 30 mintues. The materials in greenhouses however can melt or be destroyed at that temperature. A similar way to achieve the same result is to close off the ventilation during the hottest months and allow it to naturally heat itself up hot enough to solarize.

13_FERTILIZER

fertilizer pumped into the irrigation system

ORGANIC FERTILIZERS
_using organic fertilizers is easy and inexpensive. All types of plants need different levels and types of fertilizer

14_TIMELINES

DAILY:
_class hours from 8:30-3:17

fertilizer pumped into the irrigation system

WINTER POSSIBILITIES:
-plants harvested from fall garden
-forced branches of pussy willows, forsythia, apple blossoms
-tender perennials to overwinter

fertilizer pumped into the irrigation system

EARLY SPRING:
-seedlings for outdoor gardens
-herbs, vegetable plants, flower plants for sale
-seedlights for warm-season crops (tomatoes, melons, cucumbers) to grow in greenhouse beds in summer

fertilizer pumped into the irrigation system

SUMMER:
-perennials
-tropical crops
-warm-season crops (tomatoes, cucumbers, eggplants, melons)
-seed or cuttings (figs, citrus fruits, bananas)

fertilizer pumped into the irrigation system

FALL POSSIBILITIES:
-bulbs for forcing
-lichen and moss terreria
-seedlings of cool season crops (chinese greens, collards, lettuce, herbs)
-transfers from summer plots (flowers)

15_VENTILATION/FANS


top vents


manual ventilation controls


heat sensors triggers ventilation system to open or close

-air circulation reduces problems with pests
-air change of 4 times per hour
-solar ventilation is triggered by the heat of the sun
-vents on high and low area to allow for airpflow
-tightly closed on cold days
-exhaust fans push hot upper air out and allowing cooler lower air to enter

AUTOMATED VENTILATION:
A small sensor hanging in the center (average temp) location in the greenhouse allows vents to open and close depending on the readings.

SHADING:
_shade cloth is made up a mesh connected with wires reflective material layed with clear plastic to allow to light penetration.
_close at night to retain heat
_close during intense summer days to avoid over-heating of the greenhouse

COOLING:
-best method is to cool naturally
_2nd choice would be to use evaporative cooling (more efficient than exhaust fans)

MOCK GREENHOUSE:
_lower eaves 10'
_side vents bottom edge is at 7' to allow structure to happen above head height
_upper vents at 24'

RECOMMENDATIONS:

Automated ventilation would be essential for the school greenhouse because on weekends and holidays teachers will not be around to manually control greenhouse temperature.

A more expensive system that could be incorporated would be installing a computerized weather vane on the top of the greenhouse which can determine what the controls should be set at at any given time.

16_LIGHTING/REFLECTIVITY

There are several types of lighting-most plants need at least 1,000 footcandles
-taller plants tend to need more light than small, bushy ones
-high pressure sodium or metal halide are expensive but efficient
-fluorescent lights

LIGHTING
_determined by height of top of plants growing and the footcandles each plant needs
_not necessary unless you are doing research needing consistent lighting
_sometimes needed in winter
_metal halide lights $400 each

"in any such project there is a balance between using sunlight as light and turning it into heat. Dark surfaces change more light to heat, while lighter surfaces bounce it around more. In the wintertime, duration of light is actually harder to come by than heat, so we chose light over heat."

17_AUTOMATED CONTROLS


automated controls clustered together

AUTOMATED SYSTEMS:
_depends on the reliability of users
_automated vents essential for weekends and vacation days
_weather vane on top of greenhouse can determine what the controls should be set at.

18_PESTS

PREVENTION:
-keep clean, dispose of plant parts immedieatly
-keep air circulating

insecticidal soap
-spray on plants (3-6 tabelspoods of dish liquid to 1 ga water)
-spray every 3-5 days

PEST CONTROL
_wasps and ladybugs (good bugs)
_soapy spray
_Neem
Soap spray; yellow sticky traps; predators (Encarsia formosa wasps).

greenhouse
-surround greenhouse with pavement/gravel to avoid infestation

INTEGRATED PEST MANAGEMENT
_Outdoors includes growing flowering plants near your garden plots to attract the kinds of insects you want

APHIDS

Description:
Small, pear-shaped insects with long legs; often pale green to white; may be winged or wingless; secrete a sticky honeydew; found on new buds, rapidly growing tips, underside of leaves near veins; they suck plant juices, reducing vigor, stunting plants, and transmitting diseases.
Treatment:
Squashing; heavy spray of water; soap spray; homemade spray; predators (brachonid wasps, certain predatory midges, green lacewings, ladybugs).
-if they get crowded they start being born with wings so they can move

SPIDER MITES

Description:
Nearly microscopic (less than 1/16 inch) arthropods with four pairs of legs as opposed to an insect's three pairs; create webbing strung between the leaf and stem; damage appears as leaf mottling; thrive in hot dry seasons and prefer foliage plants. Treatement:
Repeated heavy spray of water; predators (predatory mites).

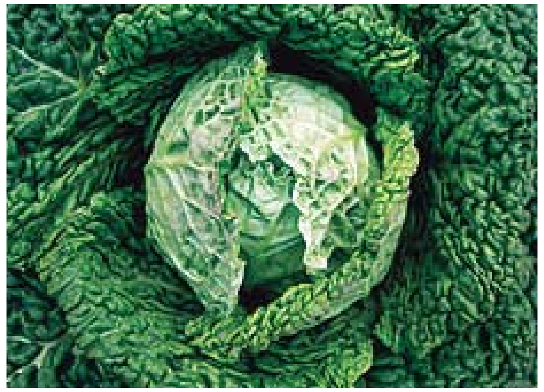
WHITEFLIES:

Description:
Tiny, delicate, white-winged insects that feed on a wide range of plants; in large numbers, they'll rise up in a white cloud when disturbed; immature stages look like transparent to opaque white dots on underside of leaves; adults congregate on tips; damage similar to that of aphids.

THRIPS
-carry viruses and can fly, spreading virus's quickly
-go outside in the summer and infest grasses around

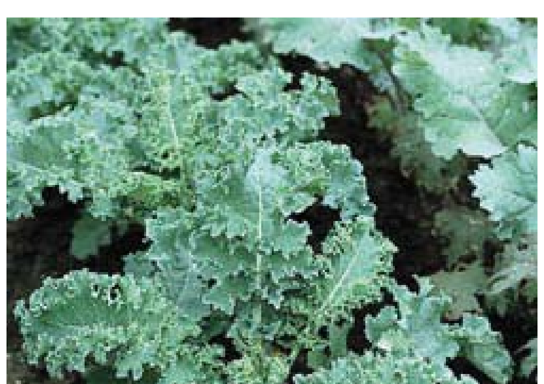
PROGRAM ELEMENTS

1_PLANTINGS


cabbage


romaine lettuce


broccoli


blue kale

As with any garden, the type of plantings should be determined by what can be grown, and what people are willing to eat.

A goal of the school is to have at least 1 meal each year prepared for all 370 students which is grown out of the greenhouse.
The main type of vegetable grown will be greens as they are less sensitive to waning light conditions in winter and colder temperatures.

Some greens varieties which could be grown are:

-seedless cucumbers specifically for greenhouse use (don't require pollination)
-lettuces first (mesclum mix is better than just lettuce for nutrition)
-spinach,
-cole crops (broccoli, cauliflower, cabbage)
-peas,
_arugula
-kale
-romaine lettuce
_bok choy

Other vegetables which need to be pollinated could still be grown and hand pollinated by students (this could be integrated into the learning curriculum.

Some of these types of plants could be:

_green beans
_snap peas
_tomatoes

HERBS:
_basil
_cilantro
_rosemary
_lemon balm

HYDROPONIC SYSTEMS:
Although the yeild is higher in hydroponic system but difficult to manage in raised beds


spinach


carrots


arugula


green bush beans


broccoli


basil


cucumbersmustard greens


colliflower


cilantro


bok choy


cucumbers


peas

2_HEADSPACE/PREP

Headspace is space for:
_soil to be mixed
_seedlings to germinate
_supplies to be organized

3_BEDS

The raised bed space is the largest space in the greenhouse and the most important.

_near ground level or raised to 24 inches
_promotes good root growth
_may have problems with soil-borne fugi and other pests
_can be constructed from wood, bricks, stone or recycled mat.
_don't use pressure treated wood, use untreated hardwood or wood treated with plant-safe preservative containing copper napthenate
_no larger than 2.5 ft unless accessed from both sides

4_CONTAINER GARDENING:

32" tables

Another option for part of the greenhouse would be to grow some plants in containers. This could happen on the storage shelves if areas weren't being used.

_recycled materials like carboard milk cartons or yogurt containers work, put holes in bottom for drainage
_unglazed clay pots are porous but heavy and breakable and are less likely to be overwatered
_to clean, soak 1 hr in solution of : 1 part chorine bleachto 9 parts water

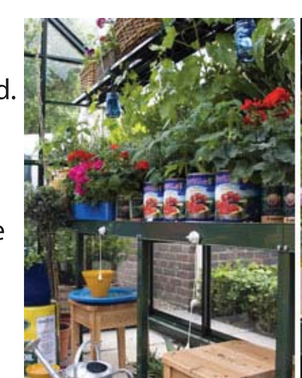
5_CIRCULATION

Circulation walkways must be 42" for wheelchair handicap accessability. The aisles in this proposal are 4' wide between the raised beds allowing for two students to stand back-to-back and use the beds as "stations"

6_DISCUSSION AREA

A small space in the greenhouse must be available to facilitate discussions which can only happen inside the greenhouse area. These might be demonstrations of how to do a project or discussion of the systems and activities happening in this space.

7_STORAGE



There are lots of items to store to keep a functioning greenhouse supplied:

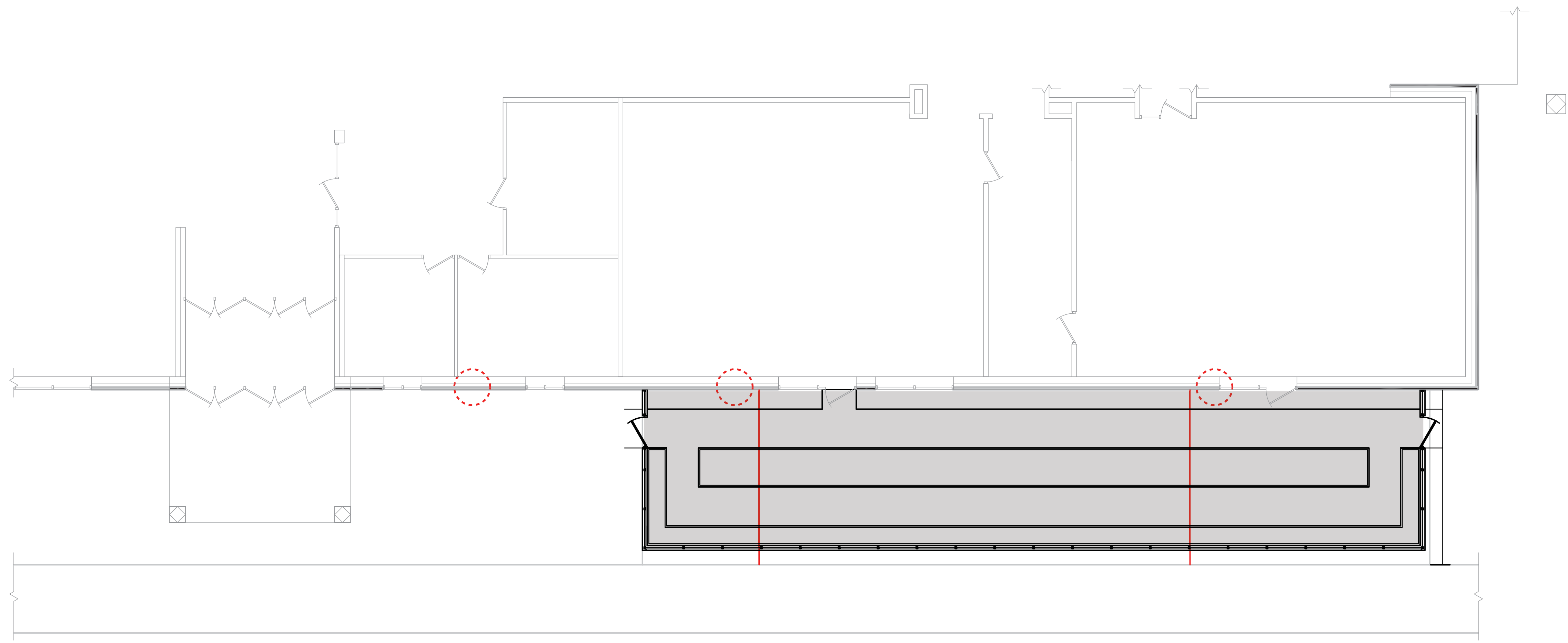
_pots of various sizes (1 gallon and 5 gallon)
_seed germination trays/heat mats
_watering cans
_soil components
_fertilizers
_other classroom supplies

DESIGN OPTIONS
SIZE OPTIONS

80' LONG GREENHOUSE

PROS
_80' length allows for more growing space

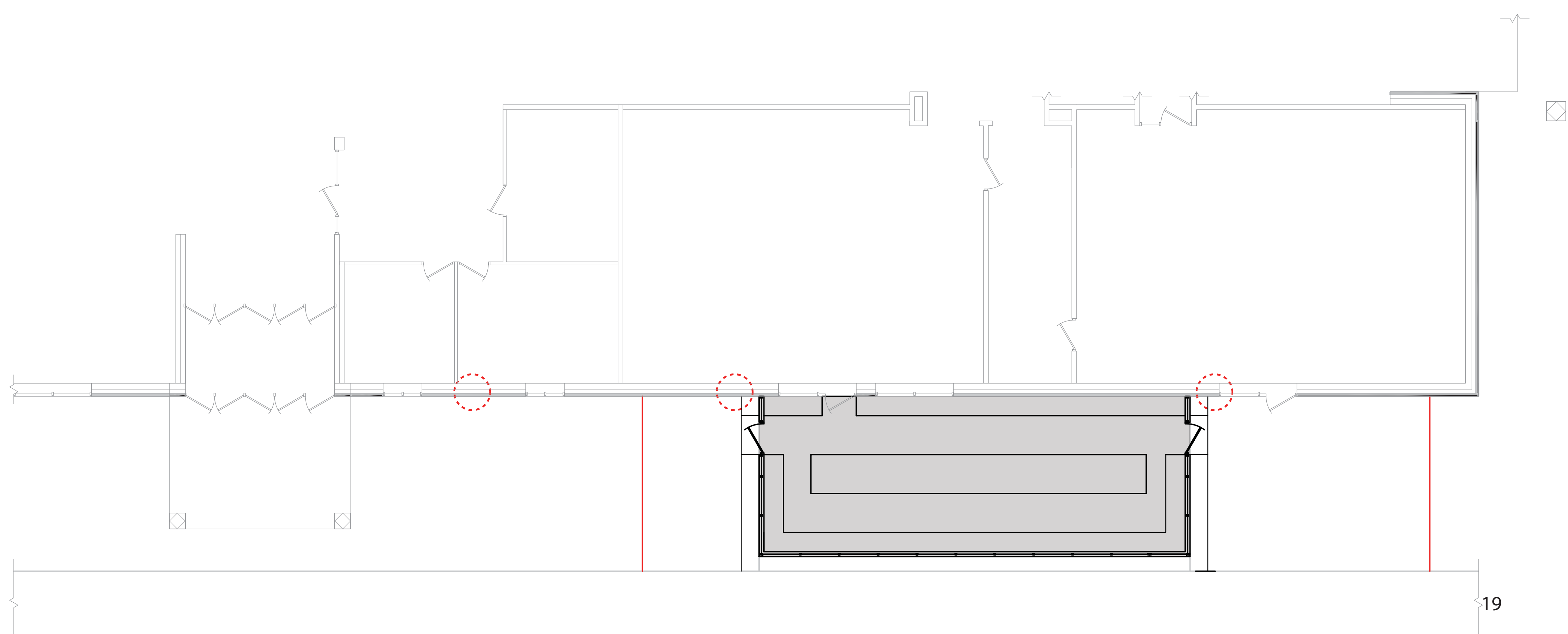
CONS
_increased cost
_ventilation issues if no top vent
_drainspout issues



44' LONG GREENHOUSE

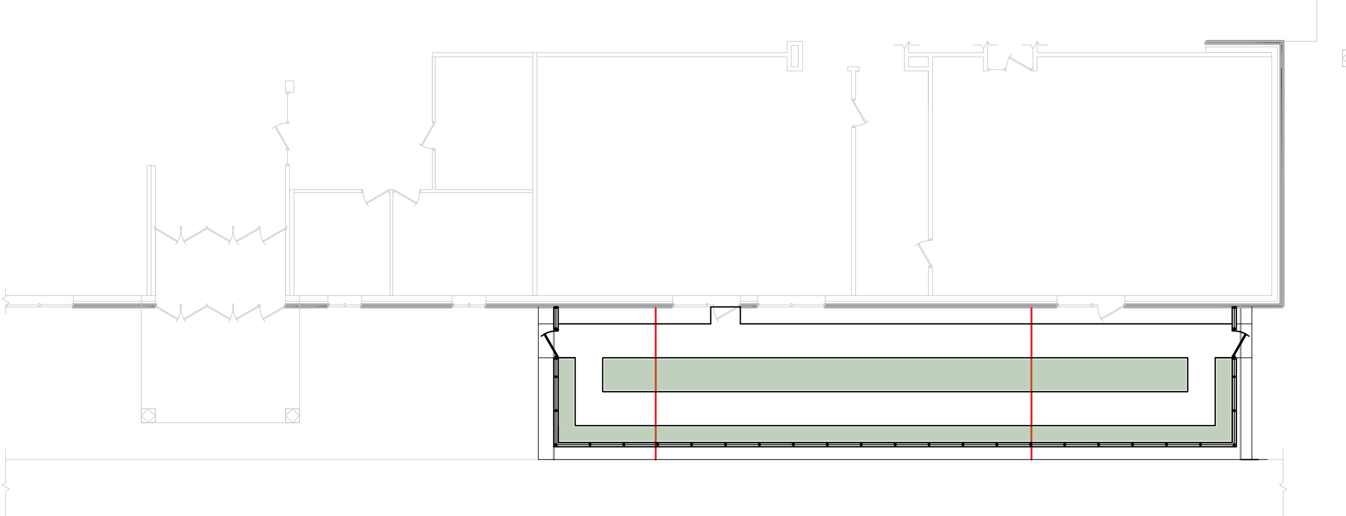
PROS
_decreased cost
_better ventilation

CONS
_not as much growing space



LAYOUT OPTIONS

80' LONG GREENHOUSE LAYOUTS

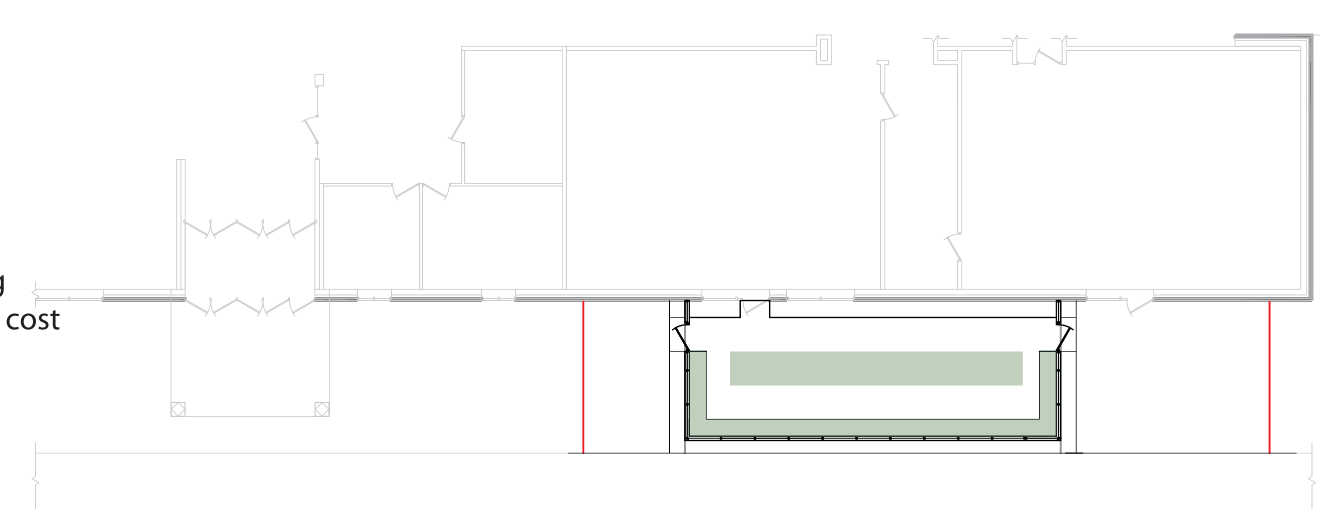


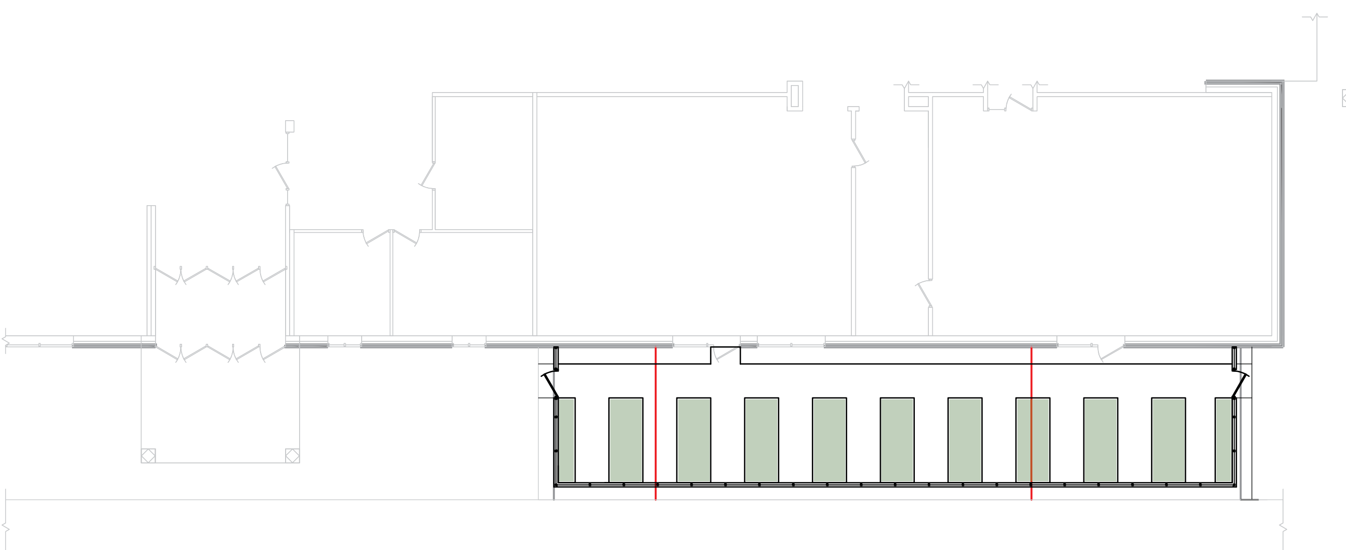
LAYOUT 1: LONGITUDINAL

growing space:
80' - 467 sq ft
44' - 256 sq ft

_one long bed maximizes growing space and minimizes construction cost

44' LONG GREENHOUSE LAYOUTS

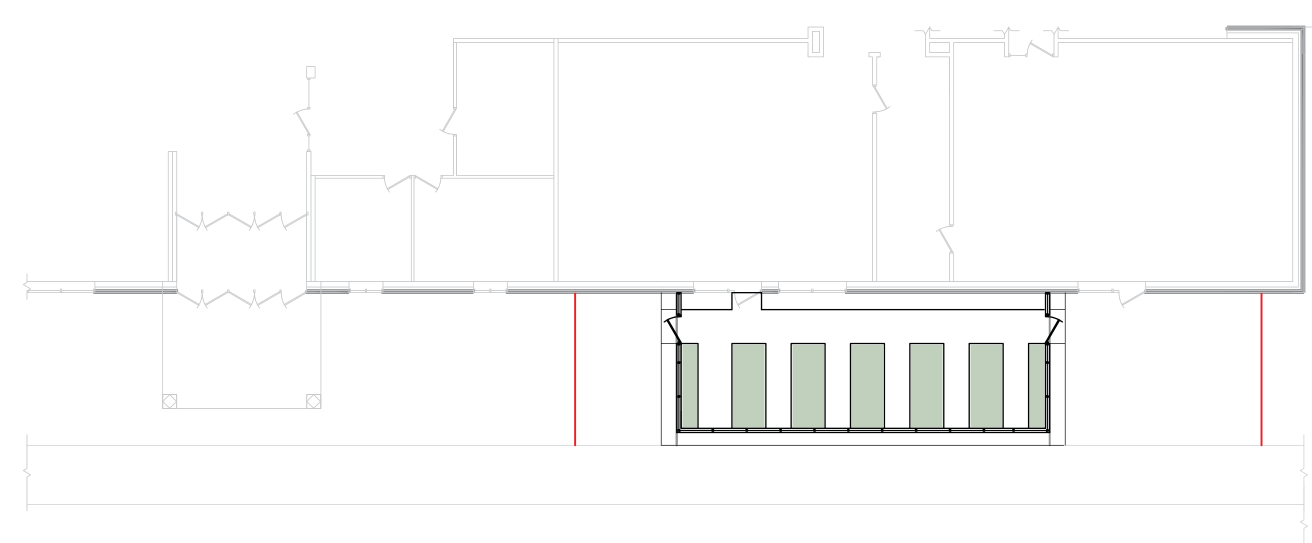


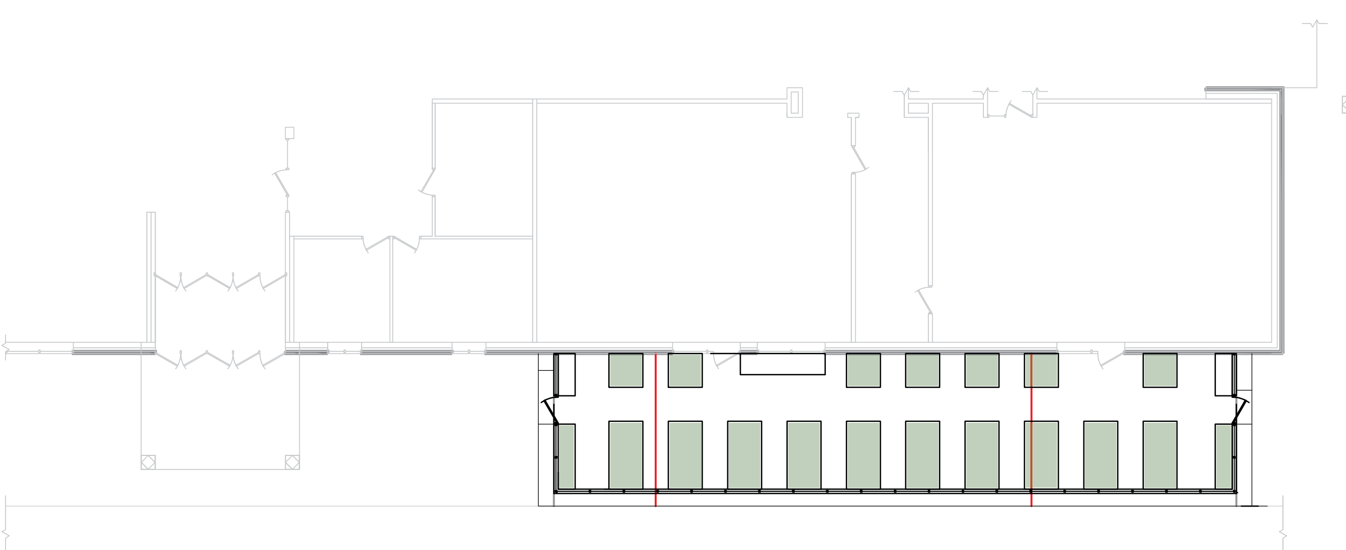


LAYOUT 2: PENINSULAR

growing space:
80' - 400 sq ft
44' - 240 sq ft

_separation of beds reduces risk of pest infestation
_4x10' beds

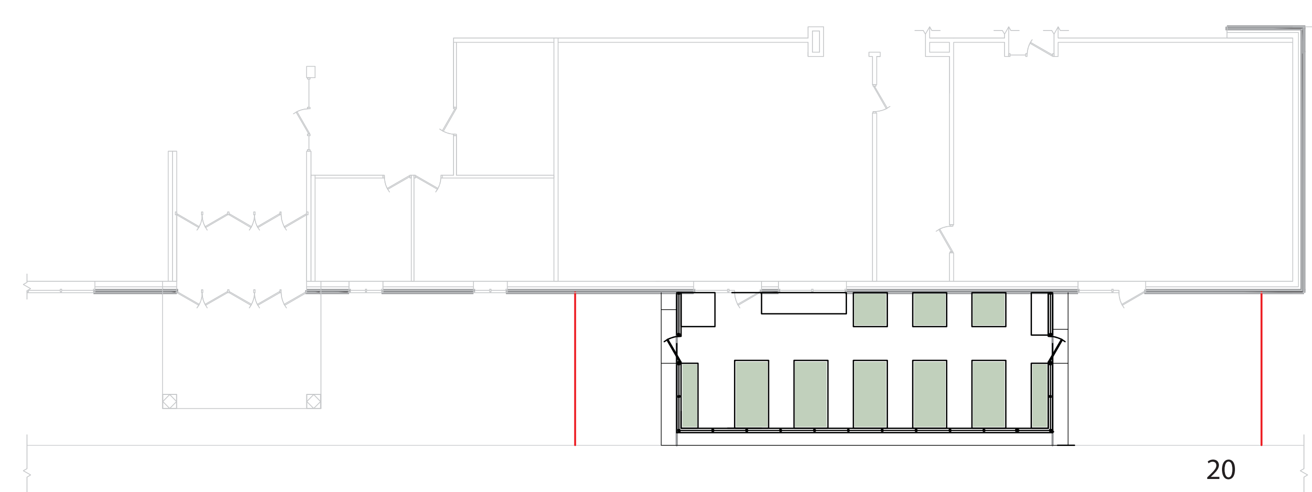




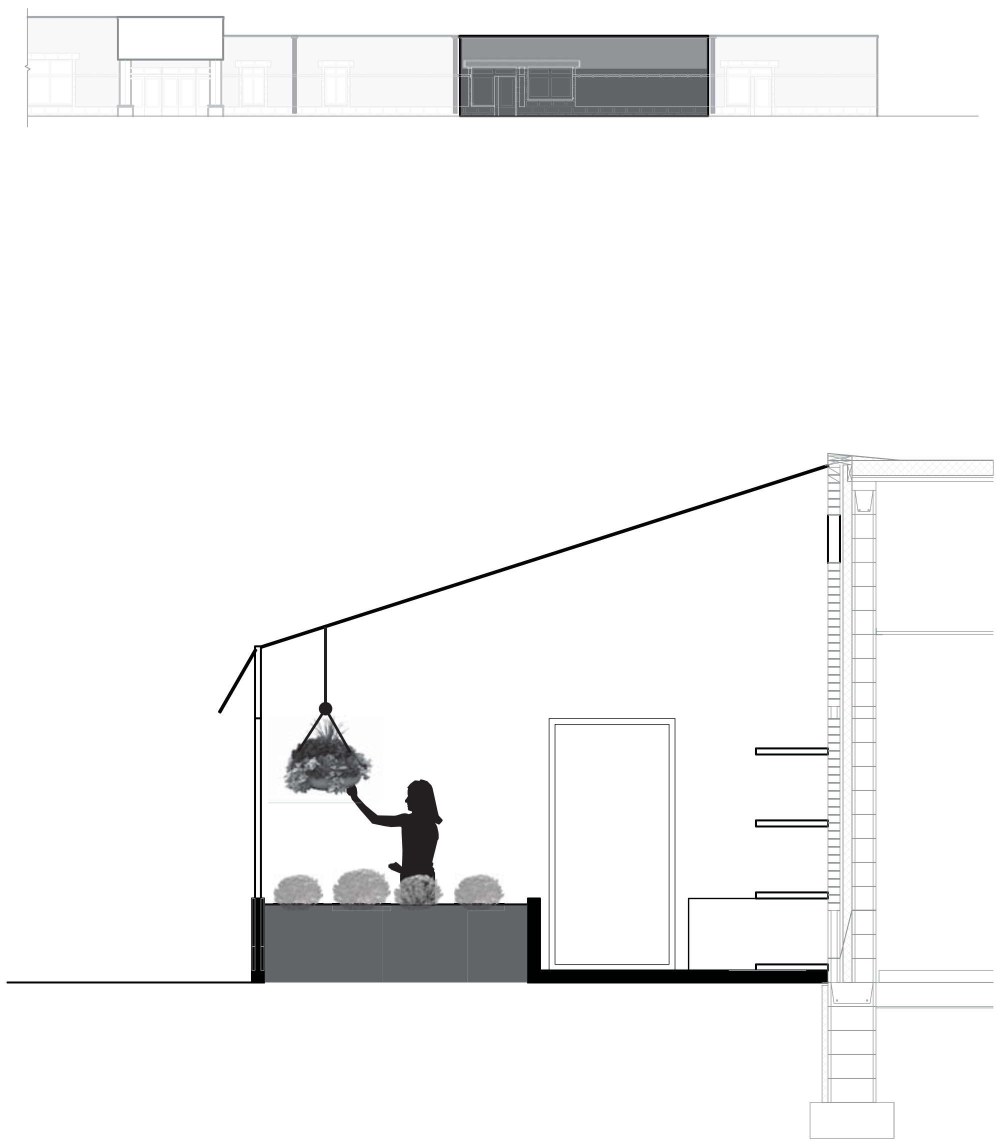
LAYOUT 3: DOUBLE PENINSULAR

growing space:
80' - 432 sq ft
44' - 240 sq ft

_4x4' and 4x8' beds



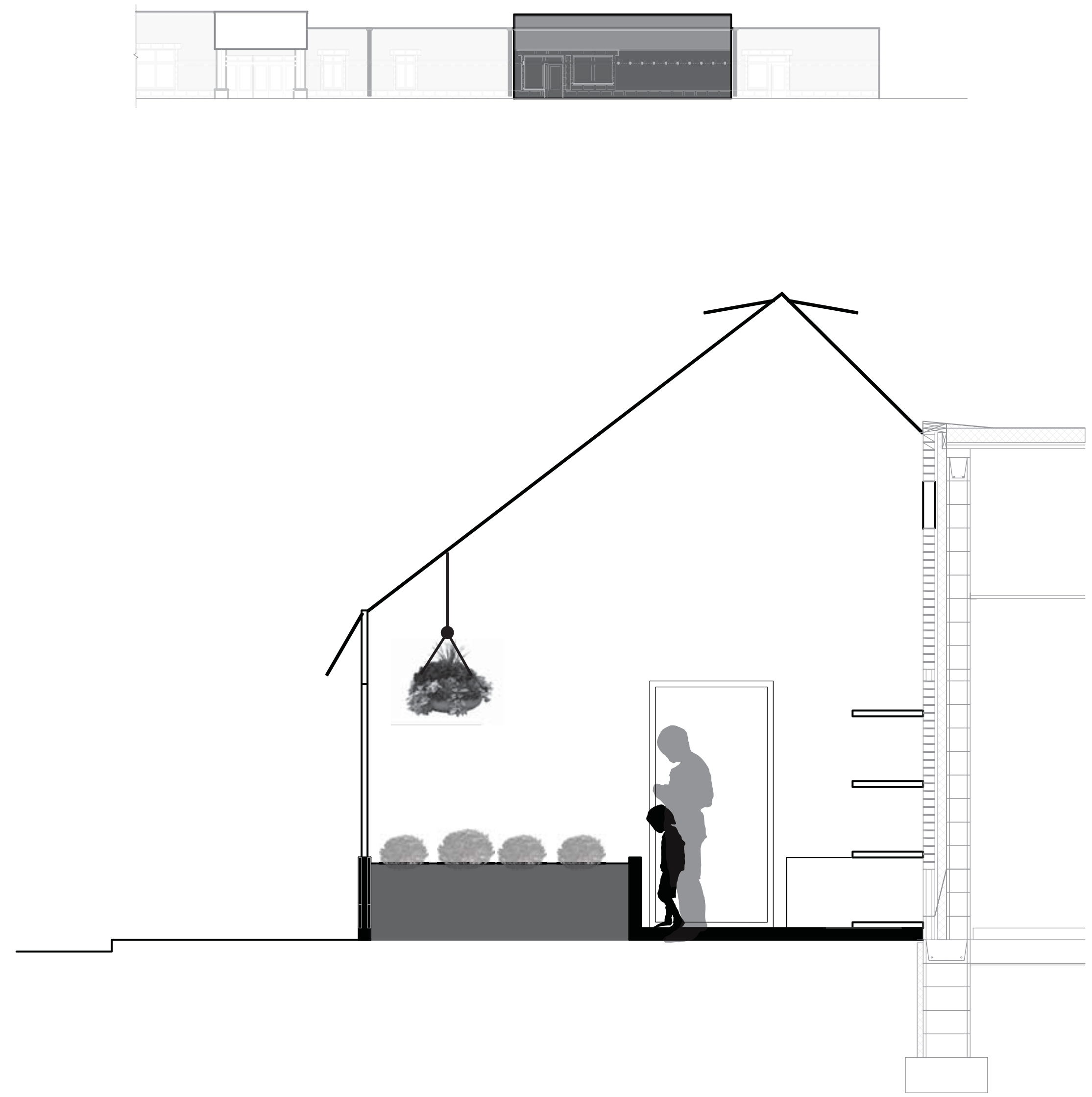
PROFILE OPTIONS



PROFILE 1

PROS
_allows for easy snow removal
_aesthetically pleasing

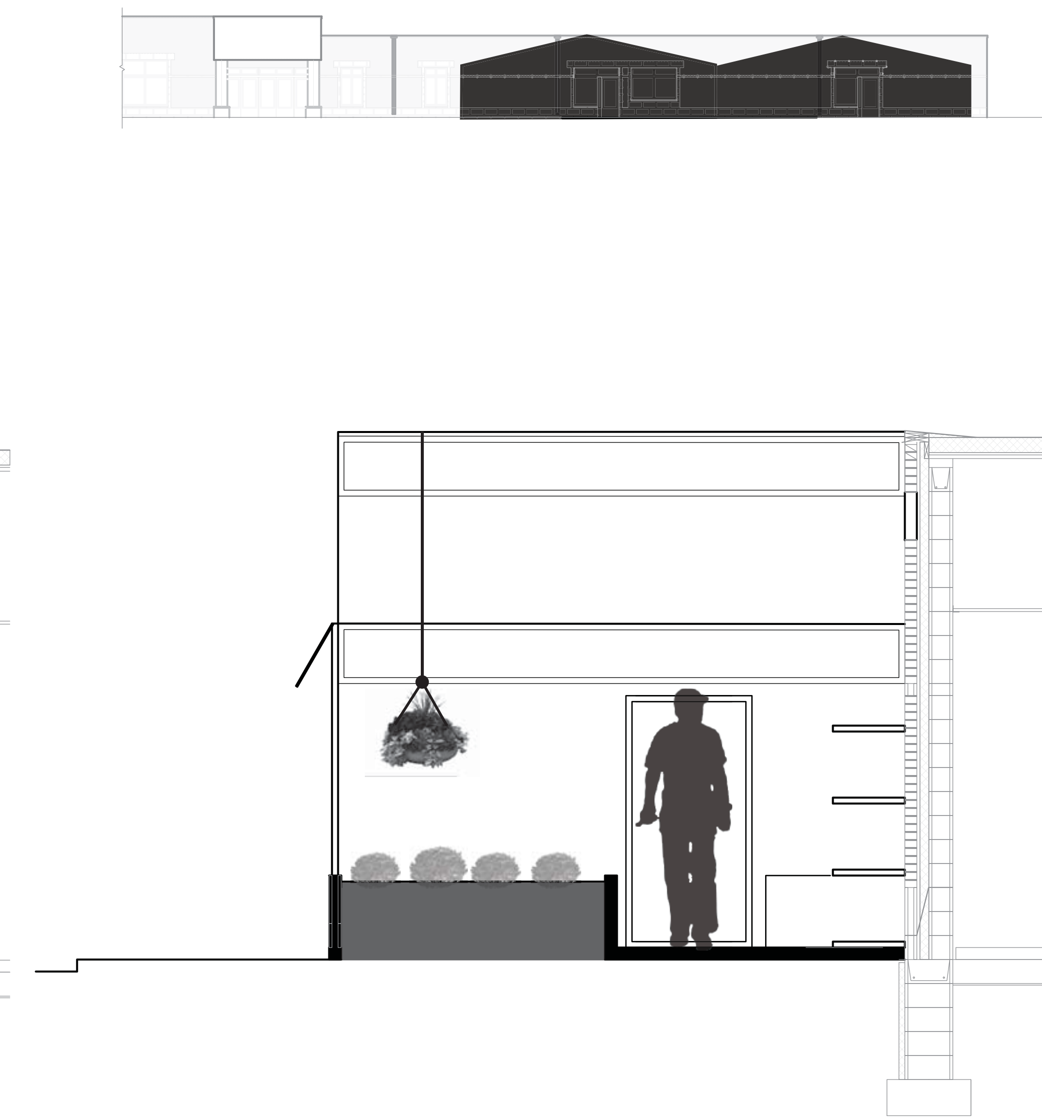
CONS
_ventilation is difficult or limited
_less overall space/volume (less ideal environment for plant growth)



PROFILE 2

PROS
_maximizes air space (good for plants)
_maximizes ventilation

CONS
_possible build up of snow on roof



PROFILE 3

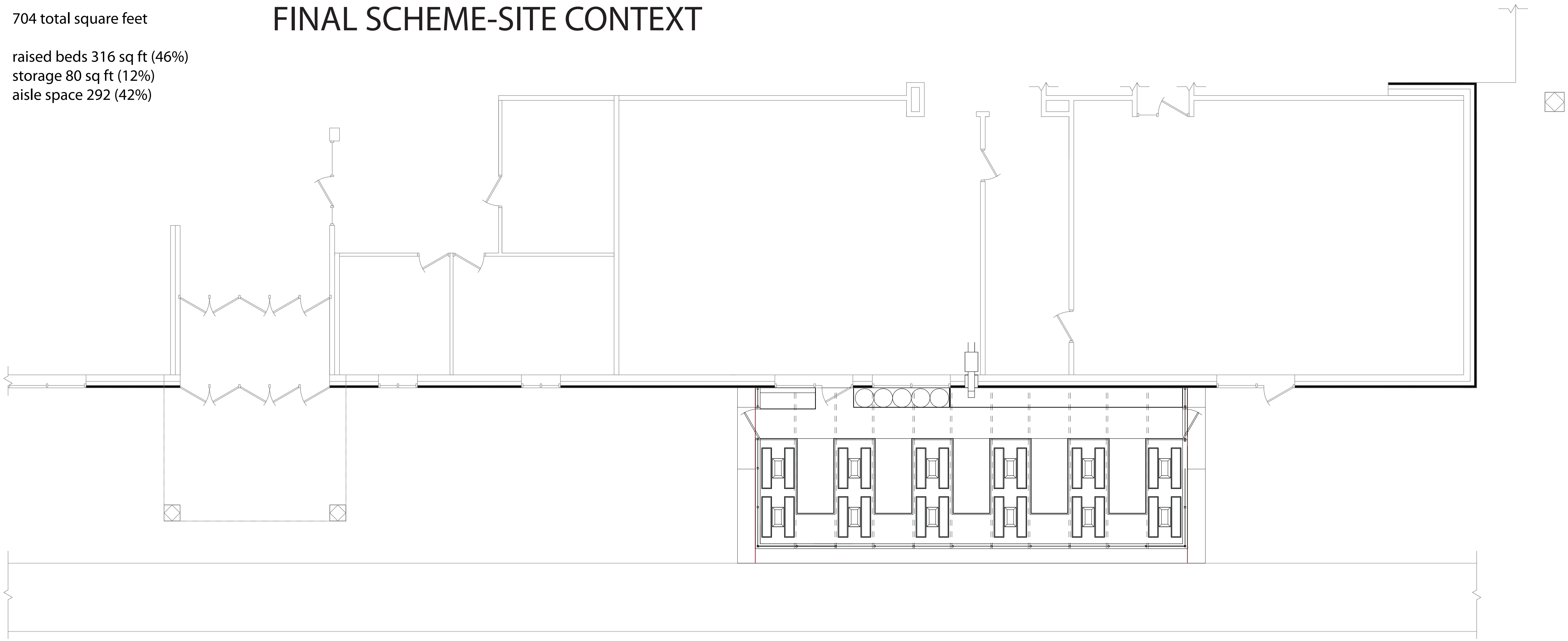
PROS
_allows for easy snow removal
_adequate ventilation

CONS
_not as aesthetically pleasing

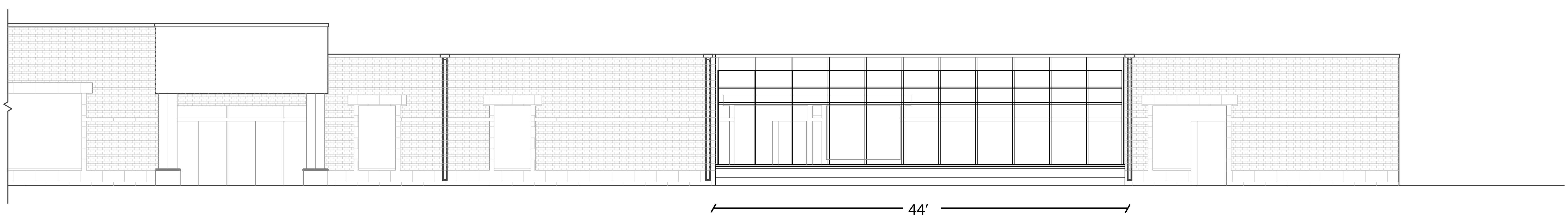
704 total square feet

raised beds 316 sq ft (46%)
storage 80 sq ft (12%)
aisle space 292 (42%)

FINAL SCHEME-SITE CONTEXT



PLAN
3/32"=1'-0"



SOUTH ELEVATION
3/32"=1'-0"

FINAL SCHEME-PLANS

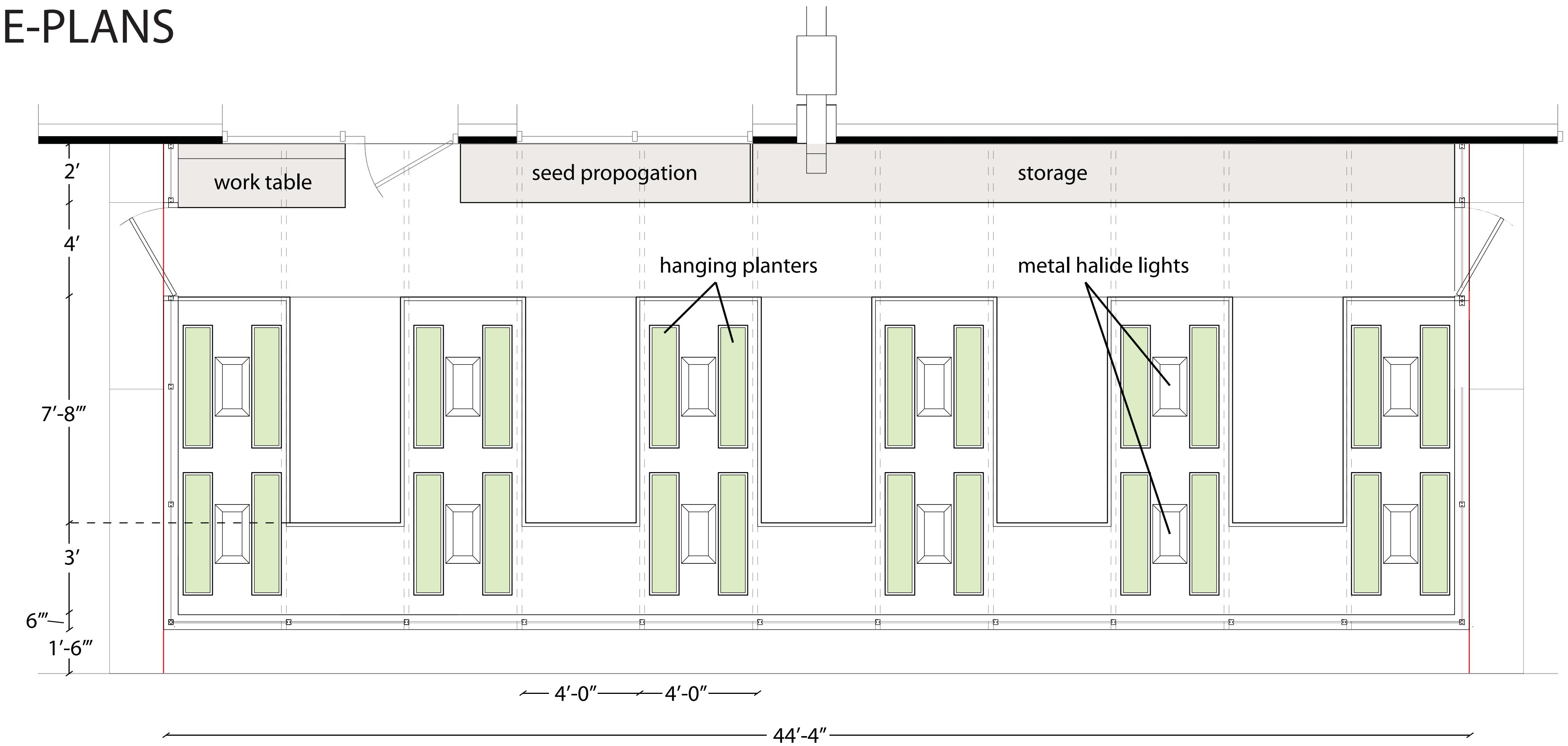
HANGING PLANTERS/LIGHTING PLAN

sq ft growing space= 96 sq ft

24 hanging planters (1'x4')

types of vegetables:
_arugula
_romaine lettuce
_mustard greens

12 metal halide 1000w lamps

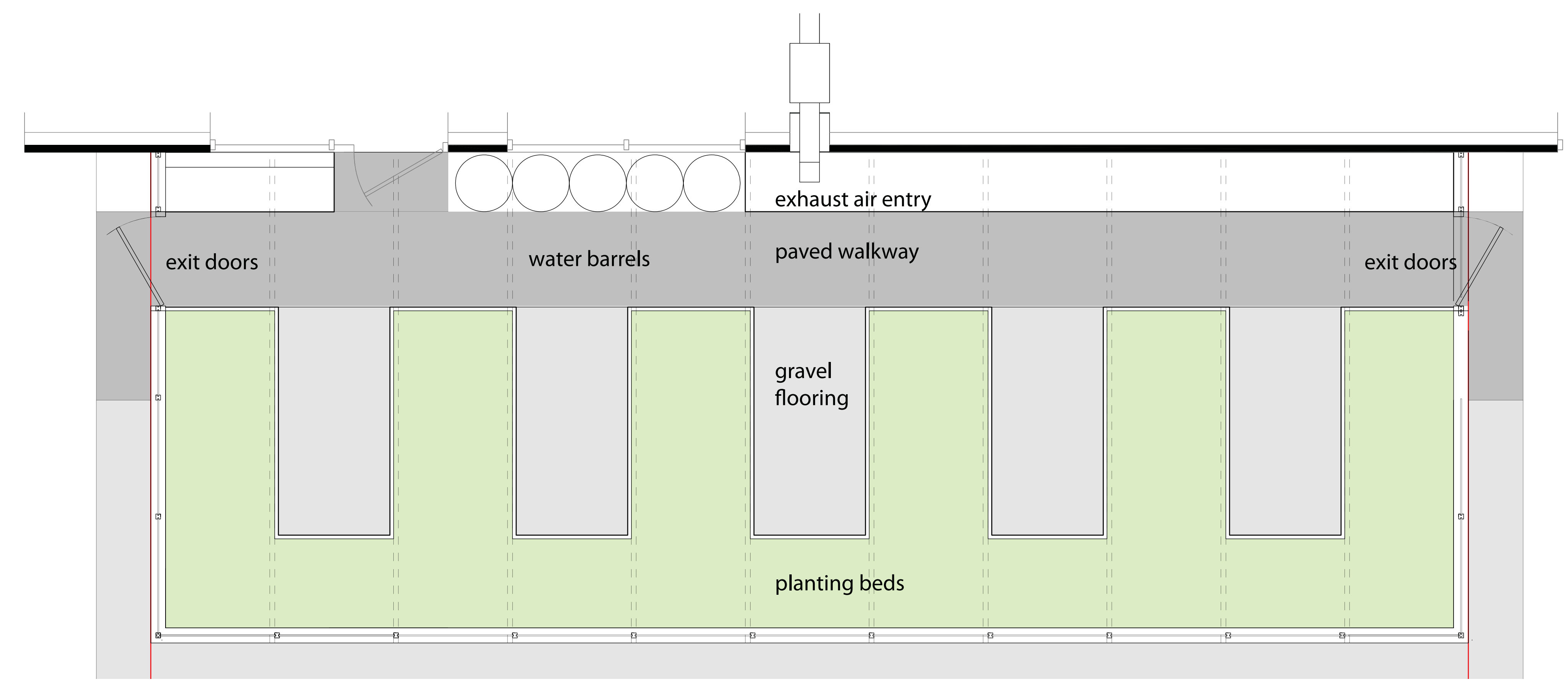


RAISED BEDS PLANTING PLAN

sq ft growing space= 316 sq ft

perimeter bed (3'x44')
=132 sq ft
penisular beds(6) (7'8"x4')
=184 sq ft

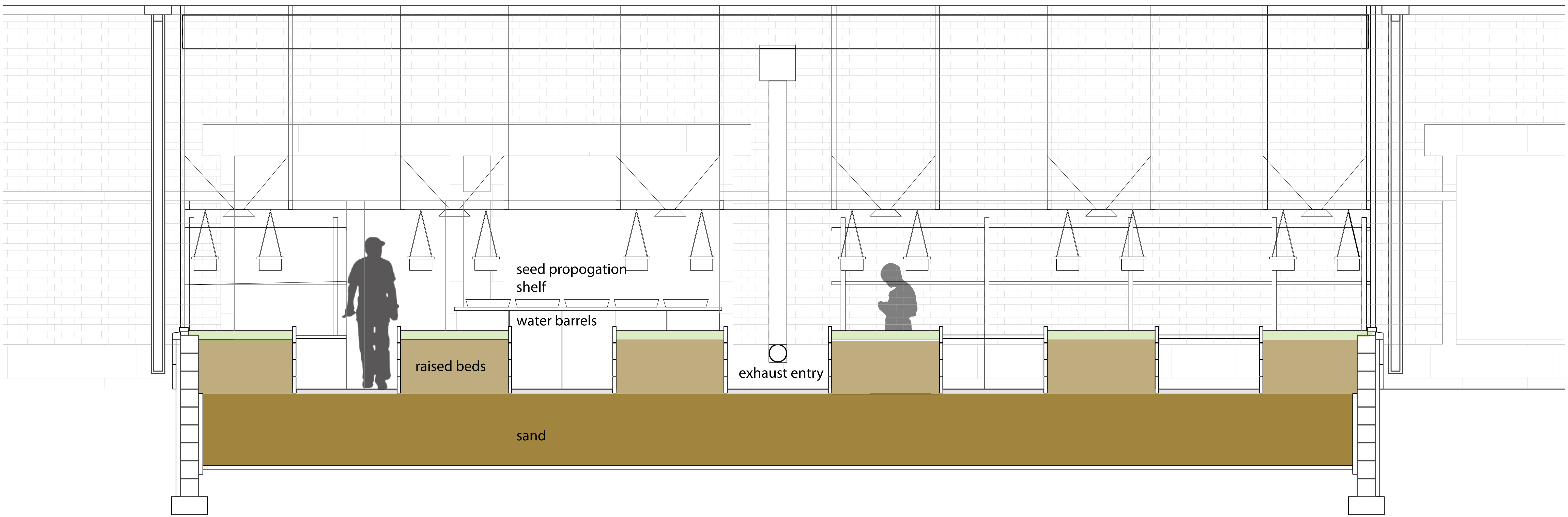
types of vegetables:
_arugula
_romaine lettuce
_mustard greens



MATERIALS:

double walled acrylic glazing
aluminum structure/mullions
beds will be built locally

FINAL SCHEME-EAST-WEST SECTION



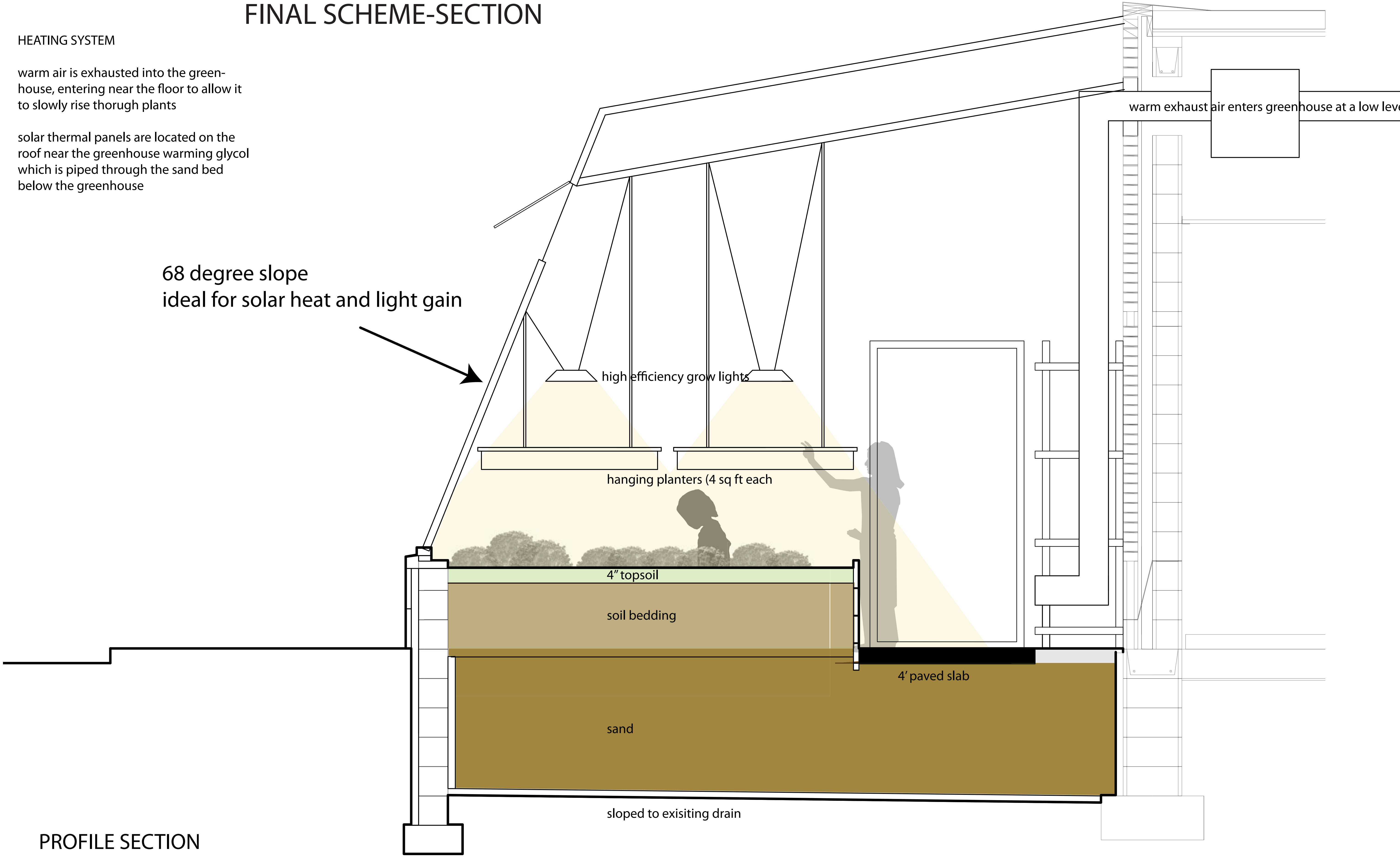
LONGITUDINAL SECTION

FINAL SCHEME-SECTION

HEATING SYSTEM

warm air is exhausted into the green-
house, entering near the floor to allow it
to slowly rise thorugh plants

solar thermal panels are located on the
roof near the greenhouse warming glycol
which is piped through the sand bed
below the greenhouse

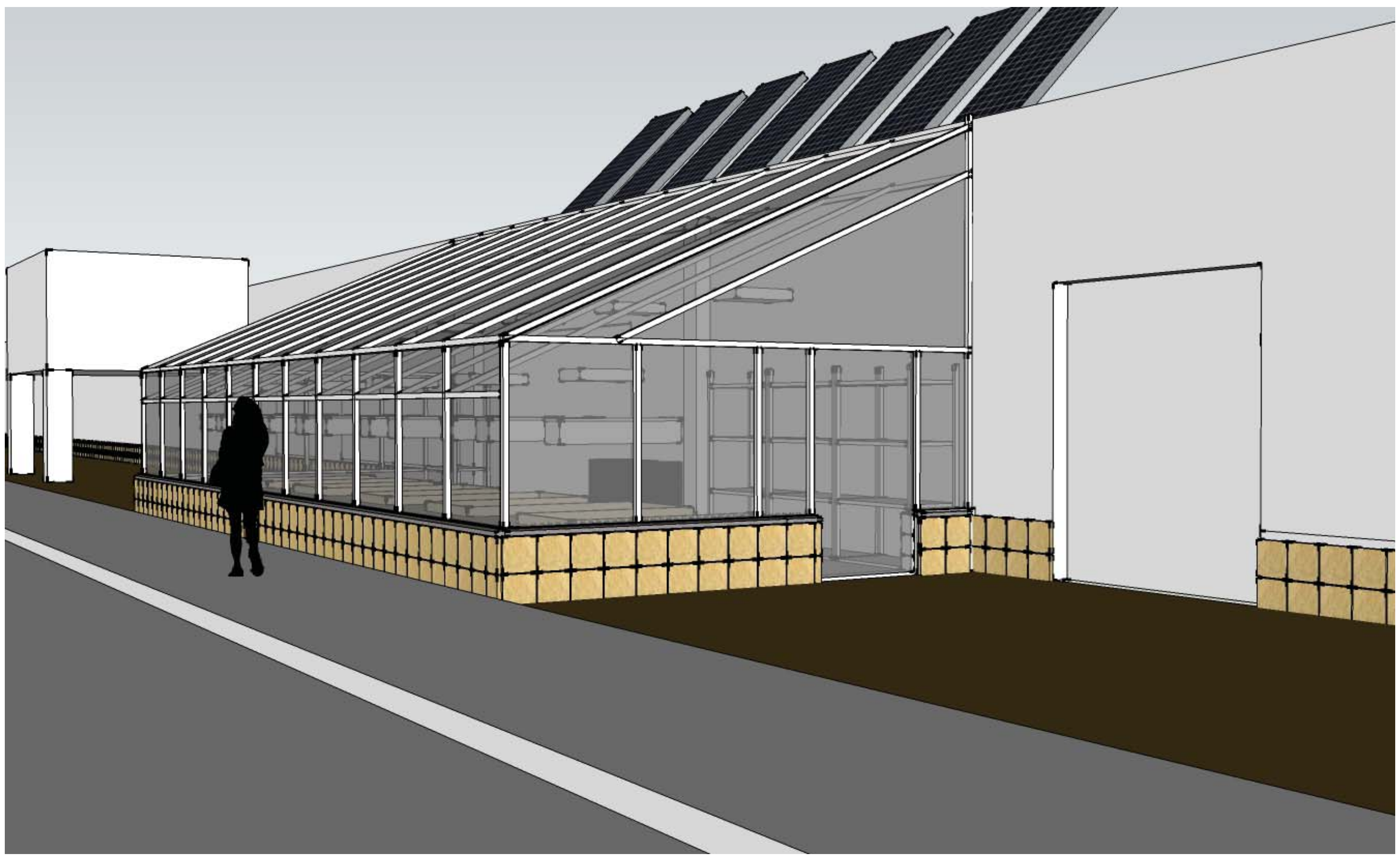


PROFILE SECTION
1/2"=1'-0"

RENDERINGS

Greenhouse interior showing hanging planter height (5'-6")

Interior of the greenhouse from science classroom entry



Greenhouse exterior showing solar thermal panels, knee wall and exit door

ENERGY DAY-TIME DIAGRAM

This diagram represents how the various systems within the greenhouse interact and take advantage of all available free energy.

1. All greenhouses by definition allow large amounts of the sun's energy to enter the enclosed structure. While most of the energy will enter the space, some of it is reflected because of structure, tinted glazing, dirt films, and snow build-up. It is important to have a maintenance plan in place for clearing snow off of the greenhouse roof, and for cleaning the glazing at least twice per year.

2. A great way to take greater advantage of the sun's free energy, is to store it in thermal mass objects, such as a concrete walk way or existing brick wall. During the day, the sun will warm the thermal mass. At night, the mass will release the stored heat energy until It has reached the constant 55 degrees of the greenhouse. Note that the thermal mass required to continually radiate heat during the longest and coldest nights of the year would be substantial.

3. Similar to the concrete walk way and brick wall, the addition of barrels filled with water would add significant thermal mass to the space and would help to absorb large amounts of heat energy (approximately 8.34 Btus of energy per gallon per one degree (F) increase in water temperature). The barrels could be used as stands in the preparation area as to not take up unnecessary space.

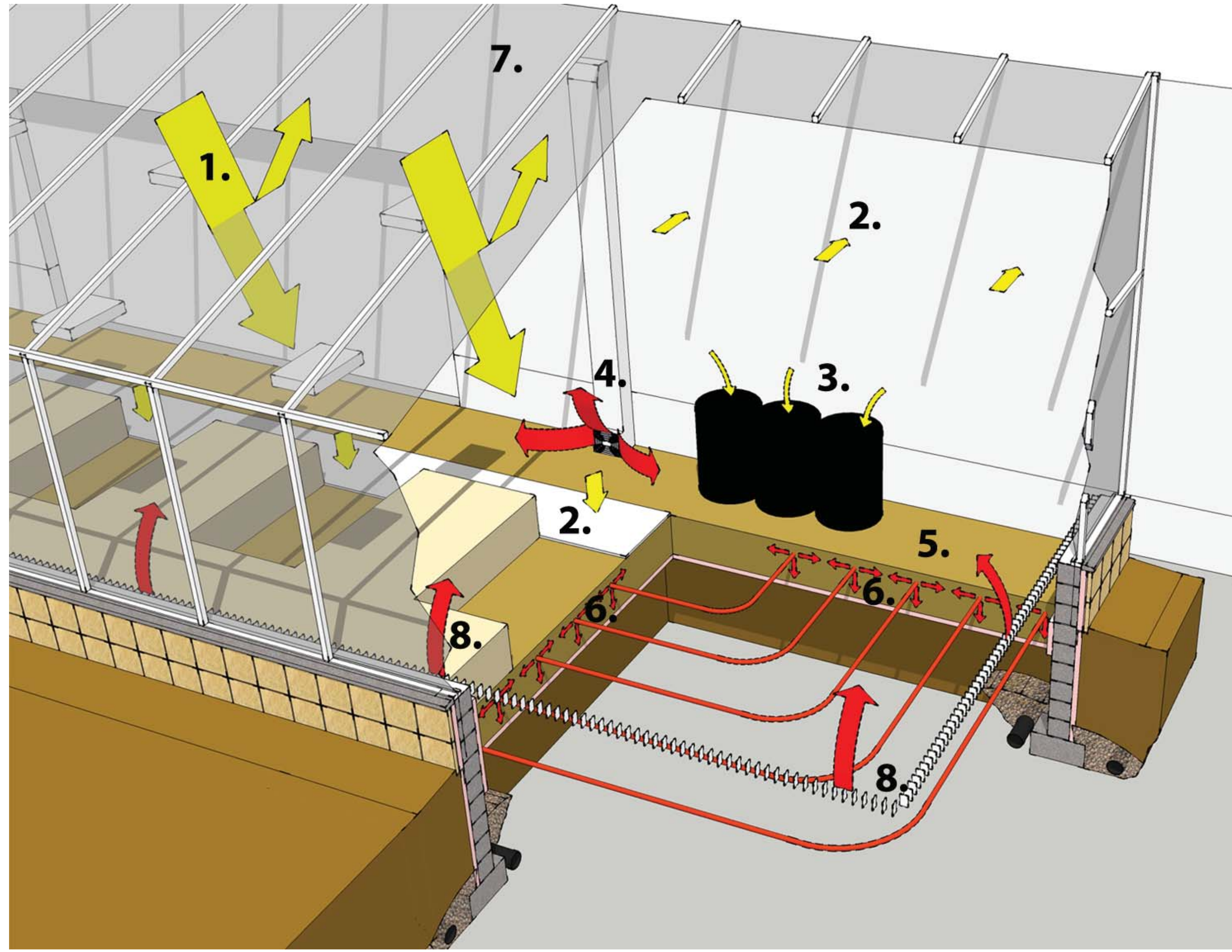
4. Existing exhaust air (air that is already exhausted out of the building) would be captured and vented into the greenhouse. Because the greenhouse temperature would have a minimum set point of 55 degrees and the exhaust air would be around 70 degrees and exhausting continuously all day (when the sun is warming the space), much of the greenhouse's (daytime) heating demand may be able to be met by the exhaust. As an added benefit, the CO2 rich exhaust air would stimulate plant growth.

5. A sand bed ranging from 18" to 24" thick would lie just beneath the greenhouse floor. The function of the sand bed is similar to the other thermal mass systems in the greenhouse, only much larger with a much larger capacity to store heat energy. The sand bed would extend the entire footprint of the greenhouse and would be highly effective in radiating heat back into the space at night. The sand bed will be thermally broken, with a minimum of 2" rigid insulation, from the outside and soil below. The sand also drains well, reducing moisture-borne plant issues.

6. To heat the sand bed, a fluid (glycol) system or loop would pass through the sand. The loop could be heated by a variety of sources, be it geothermal, biomass, or fossil fuels. Perhaps the most efficient method would be through a solar thermal system. The primary heating source would heat the space to the 55 degree set point (if needed). At that point, all excess heat would be "dumped" into the sand bed, where it will radiate back into the cooler greenhouse when needed.

7. An air-tight envelope is critical for reduced air infiltration, which is the most significant cause of heat loss.

8. The finned tube heating system will wrap the entire perimeter of the greenhouse, and act as the primary source of heat. (see energy schemes).



ENERGY NIGHT-TIME DIAGRAM

This diagram is very similar to the daytime diagram. The main difference is that rather than the focus being on storage of energy, it is now on releasing the energy in an efficient and effective manor.

1. At night, the glazing becomes the enemy, as it allows for very rapid heat transfer, and amplifies the importance of an air-tight envelope.

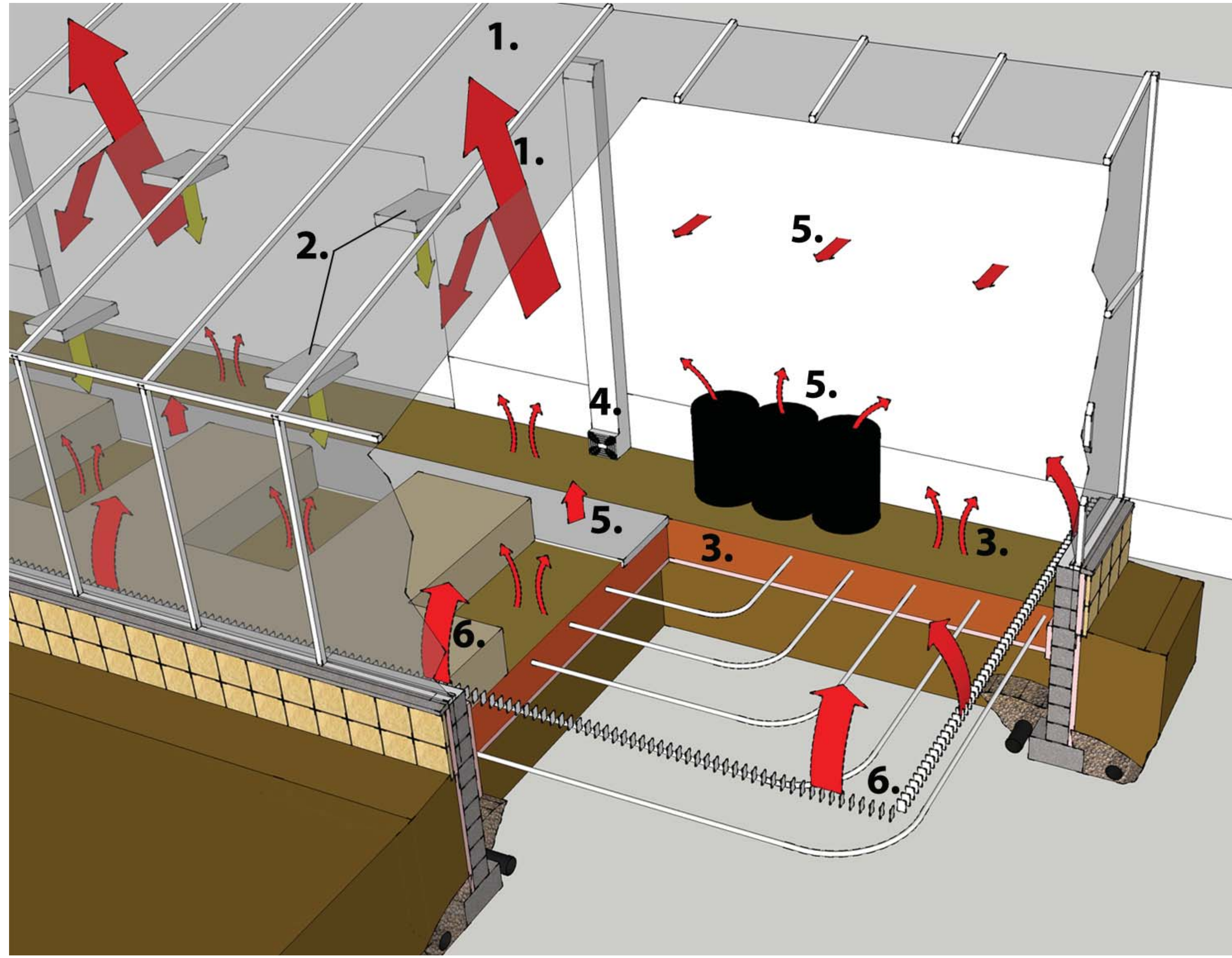
2. When the grow lights are on, they not only provide valuable light, they will add considerable amounts of heat energy. Given the schedule of the C-G-B greenhouse, excess heat will not be a problem. Unfortunately, these lights are scheduled to operate for 11-12 hours on average, and will not help offset peak heating loads at night.

3. The heat energy "dumped" and stored in the sand bed is released throughout the night, until it balances at the same temperature as the greenhouse. This release of heat energy will conserve considerable amounts of energy and reduce the peak load that a back-up heating system will experience.

4. The school's current mechanical schedule does not exhaust air at night. The larger heating load at night will not be supplemented by exhaust air unless the school decides to change mechanical schedules.

5. All the various thermal mass systems in the greenhouse release their heat after the sun goes down. Because the concrete walk, brick wall and water barrels have marginal thermal mass, the heat released by these systems will be significant for only the first couple hours after dark, and are only effective if the sun is shining during the day.

6. The finned tube heating system at the perimeter of the greenhouse becomes an even more important feature at night, as there is only a few other sources of heat energy during what can be very long and cold nights during December thru February.



ENERGY MODELING

For energy modeling purposes, greenhouse operation was assumed to start in early September and run through early May and maintain a constant temperature of 55 degrees Fahrenheit (unless noted otherwise). All options are modeled with an aluminum frame / acrylic glazing system with very little infiltration. Lighting was set at a threshold of 800 footcandles and duration of eleven hours of light per day.

Greenhouse (44'x16')
Total energy consumption _ 222 kBtu/SF/yr
Heating _ 193 kBtu/SF/yr
Lighting _ 29 kBtu/SF/yr
Average household energy consumption _ 50 kBtu/SF/yr
To increase constant temperature to 65 degrees would increase heating cost and consumption by 45%

Lighting _ 6,027 kwh/yr
Total operating cost @ $.044 / kwh: $265/yr

Energy_Analysis:

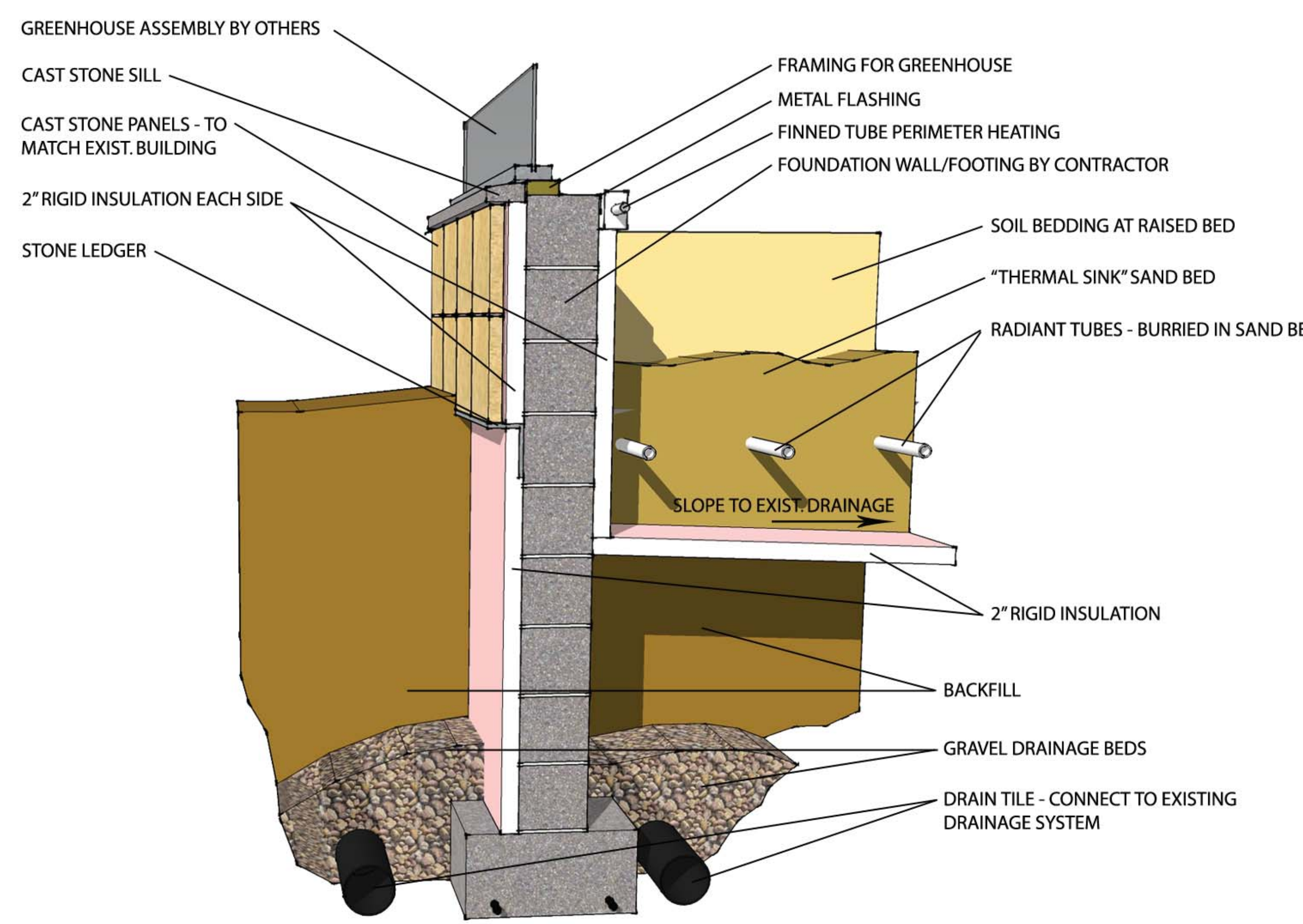
To best determine the most efficient and economical greenhouse energy solution, it is important to note that growing vegetables in the winter in our climate takes a significant amount of energy, mainly heating and lighting. A greenhouse wall will typically have an R-value of between one and three. A typical new home built today will have R-values around 21. As the energy modeling identified, it will take roughly 4.5 times as much energy (per square foot) to operate this greenhouse than a typical house. Considering the amount of energy required to operate the greenhouse and to do so on a fixed operational budget, we looked at various energy sources and aimed to take advantage of all passive or free energy that might be available.

The three scenarios outlined below aim to meet the criteria of sustaining growth in the greenhouse year-long, operate at very low cost, have very low maintenance levels, are highly efficient, and have minimal ecological impact, all while having various opportunities for learning and classroom integration. Perhaps more important than which energy scheme is chosen is that the students and staff become familiar with the systems, their operation, and the most efficient set points for the vegetables being grown. In all scenarios the installation of monitoring equipment (to measure energy input, both heat and electric) is highly recommended to confirm that the system is operating at peak efficiency, as well as for curriculum research opportunities. These monitoring devices should be relatively easy to get through the local utility at reduced costs or even free of cost.

Scenario one and three take advantage of a sand bed or "heat sink" to help level out the peak heating demands at night during the winter months. Ventilation will be automated and regulated to maintain CO_2 levels, temperature and humidity levels most appropriate for plant growth. During normal school hours, exhaust from the school, which is normally vented outside, will be vented into the greenhouse. This approach will take advantage of otherwise wasted heat energy, and air rich in growth-stimulating CO_2, and do so completely free of cost! During warmer months, the exhaust alone may be sufficient to heat the greenhouse during the daytime. At night, a traditional exhaust-ventilation will occur, and additional heat will be made up by the systems outlined below. A CO monitor will need to be added in the space to confirm that the Indoor Environmental Quality (IEQ) is always sufficient for human occupants.

ENERGY DIAGRAMS

The C-G-B school greenhouse has ample opportunities to take advantage of some of the latest technologies in efficiency and energy production as well as some "tried-and-true" methods of energy conservation. The greenhouse is a dynamic and living system, and just as in the natural world, needs to respond to the diurnal and seasonal changes in heat, light and weather. The following diagrams outline how the proposed greenhouse can be expected to operate and take advantage of the various design interventions over a 24-hour period.



SCENARIO 1
SOLAR THERMAL + EXISTING HEATING

This scenario consists of two phases.

Phase I (Solar thermal + existing heating)– The primary system of Phase 1 would be a solar thermal system (which would provide approx. 25% of annual energy needs) that would switch between heating the greenhouse space to heating the sand bed (when interior temps are sufficient). The sand bed becomes a "heat sink" for storing excess heat during the day and releasing it into the greenhouse at night, thus reducing night time heating load on the back-up system (see diagrams). Because of the significant amount of warm exhaust air that will be vented into the greenhouse during school hours, most, and on some days, all of the solar thermal heat could be used to heat the sand bed. The back-up system would consist of "splicing" into the existing heating system and taking advantage of the excess capacity of the existing boilers, which would essentially be nearly "free" energy.

Pros: The systems are very simple and would have low maintenance. The combination of these systems is incredibly efficient, mainly taking advantage of free and wasted energy. This scenario would likely have the lowest operating cost.

Cons: The system still requires burning fossil fuels (the existing system). This system would require work to be done within the existing school – retrofitting.

Phase II (Solar thermal + biomass gasification)– Phase II would build on phase I and take the existing heating system (not the exhaust system) off-line and connect to the gasification - co-generation system (heat and electrical production system) that the U of M-Morris is currently working on. The Graceville team would work closely with the Morris team and Lowell Rasmussen during the development of the system to match the needs of the greenhouse with the direction of the gasification project. The solar thermal system from phase I could still be used for heating the sand bed and reducing load, but the Morris team may be more interested in analyzing the co-generation system as a stand-alone system (this will develop as conversations grow with the Morris team). In this case, the solar thermal system can be used to preheat intake ventilation air or domestic hot water for the school building.

Pros: This would be one of the first projects like this in the country and would likely lead to broad exposure for innovation. The system would heat and power the greenhouse and would have extremely low operating costs – fuel would be waste agricultural products (taking advantage of local fuel sourcing). The ecological footprint of this system would be extremely low. The project would be a fantastic opportunity for integration into the Science curriculum as well as for future partnership(s) with the U of M-Morris.

Cons: There is some significant coordination involved with U of M-Morris. There would be coordination and capital costs involved with using the existing heating system for a while and then switching to the gasification system – the system should be able to tap into existing heating and electrical layout to avoid additional installation costs. System cost may be an issue (to be determined).

SCENARIO 2
GEOTHERMAL

In scenario two, a stand-alone geothermal system would be installed. The geothermal system extracts heat from the ground and releases that heat energy through the finned tube system within the greenhouse. The sand bed would not be used in scenario two because the ground loop the geothermal system is pulling heat from acts very much like the sand bed would. In fact, the sand bed in this scenario may actually decrease efficiency. Solar thermal could be coupled with the geothermal system, but because of the greenhouse scale, it would be too expensive to install and would have negligible impacts on efficiency. Analysis of a PV system (to offset geothermal pump operating costs) suggests installation costs to be excessively expensive at this time (given the cheap utility rates the school pays). The payback would be approximately 25 years! To improve long-term geothermal efficiency, the system could be balanced by using it in the summer to cool the office spaces (this would balance the system because it would draw heat from the ground in the summer and replace heat in the winter).

Pros: Because there is only one system involved in this scheme, it would be very straight forward. Geothermal is efficient – for every one unit of energy used, the greenhouse would get three units in return. Geothermal is very reliable and low-maintenance.

Cons: Installation costs are high, and operational costs can be high because the system uses electricity, which is typically more expensive than fuels. A ground loop or wells would need to be dug/drilled nearby (space issue). This system would be the least ecologically-friendly and likely the most expensive to operate of all three options.

SCENARIO 3
BIOMASS GASIFICATION

This scenario suggests working closely with U of M-Morris and re-defining the greenhouse energy systems time-line to match that of the co-generation (heat and electrical production system) project at Morris. Lowell Rasmussen, at the Morris campus, is willing to work with the design team and the Graceville team moving forward. He has shown interest in having the teams present the greenhouse project and hear feedback on the co-generation project, and potential opportunities as it pertains to the greenhouse energy system. Potentially, the greenhouse could be built as currently scheduled and the effectiveness of the passive systems at maintaining a relatively warm greenhouse could be tested (without an active heating system).

Pros: Installation cost would be reduced in this scenario because there would be no need for multiple systems or the cost to change from one system to the co-generation system in the future and operating costs will be extremely low. The system could be used at the C-G-B school as a demonstration project. Engaging students and faculty at the U of M-Morris, would add "engaged" individuals to the project, reducing the chance that the project will "lose steam over time. See "pros" for Scenario one phase II.

Cons: The project may be delayed and team/community members may begin to "lose interest" if waiting for another involved party. System cost may be an issue (to be determined).

Finally, the expense of lighting can be reduced, but ultimately lighting is critical in having a successful greenhouse (specifically in the winter months). Analysis for a PV (Photovoltaic) system was done to offset lighting energy use, but because the school's current electrical rate is so low, payback on the PV system would extend nearly 25 years (beyond the system's warranty). In addition, PV requires regular maintenance, and significant electrical system investments, which would likely be better spent elsewhere at this point. The guidelines for the lighting would be to find previously-used high-pressure sodium or metal halide lights. The lighting levels can be adjusted to meet the needs of the plants while minimizing total output and thus total energy consumption and cost (classroom participation opportunity).

ENERGY COSTS

Scenario 1 - Phase I (solar thermal + existing heating)
Installation costs (existing system): $10,000 - $20,000 approx.
Installation costs (solar thermal system): $26,500
Total Installation costs: $36,500 – $46,500
Operational costs: $0 - $500 approx.

Scenario 1 - Phase 2(solar thermal + biomass gasification)
Installation costs (gasification system): to be determined
Installation costs (solar thermal system): $26,500
Operational costs: $0 - $200 approx.

Scenario 2 (geothermal)
Installation costs: $30,000 - $35,000
Operational costs: approx $550

Scenario 3 (biomass gasification)
Installation costs: to be determined
Operational costs: $0 - $200 approx.

Lighting _ 6,027 kwh/yr
Total operating cost @ $.044 / kwh: $265/yr

CURRICULUM

WHEN WILL THE GREENHOUSE BE USED:

_greenhouse is an added piece to the curriculum
(time at the end of the day as students finish other work)
(study hall)
_future integration depends on the ability to meet standards

STUDENT DEMOGRAPHICS:

7th grade (Earth and Life)
8th grade (Life and Physical)
9th grade (Earth Scienve)

25 students in each class (3 classes - 82 students total last year)
-5 class periods
_Jr and Sr study hall time
_All high school students will have worked in the community garden at this point

POSSIBILITY TO INTEGRATE INTO CURRICULUM
_compost tumbler by community garden
_3 meals total will be fed
_Foods class integratoin?
_Volunteer opportunities
_Other groups that would be involved

OPPORTUNITIES FOR SCHOOL SYSTEM:
cafeteria waste
pencil shavings
-integraiton with art system

EXPERIMENTS:

HYDROPONICS

-hydroponic area connected to fish tank; fish tank captures heat (heat sink) which housing fish whose fertilized water could be used in hydroponics
-wading pool (see what grows)

POLLINATION

-potted raspberries: leave them outside until about december, they need 6 weeks of 42 degrees or lower weather as a necessary part of their life cycle. then bring them in and they will produce fruit by end of January and into Feb.
-nutients
-simulate different habitats

SEASONAL SUN

-explore sun's movement by determining average height of the sun at noon in each of the school year seasons
-record the path of the sun on the greenhouse walls, adhesive dots
-understand how physical factors and climate relate to plant type and growth

MICROCLIMATES IN GREENHOUSE

-hot air near top, cool air drops
-air next to glazing is cold in winter and hot in summer
-sunlight enters greenhouse at different angles throughout the year
-shade cuts down on light intensity

THE GREENHOUSE EFFECT

All greenhouses operate on the same basic principle. Radiant energy (light) from the sun can pass through transparent and semi-transparent materials. When the light arrives inside a closed space, it is absorbed by the surfaces within, then radiated again as thermal energy (heat). That energy is less able to pass through the transparent or semi-transparent materials, so the heat is trapped inside. Anyone who has entered a car parked in a sunny location knows what trapped heat feels like! This heat energy warms the air, enabling plant growth. As a simple but powerful exploration of this phenomenon, invite students to place a thermometer inside a clear, closed glass jar in the sun. Place a second thermometer next to the jar. After half an hour, compare the two temperatures. Your students may be surprised at the difference between the two readings.

SHADOWS AND LIGHT

Invite students to explore how objects' shadows change through the day and year. Have them use popsicle sticks to mark the path of a tree, flagpole, or other object as it moves across the ground during the day. You can also map the shadow's size and location during different seasons, and prepare overlays showing shifting patterns of light and shadows. Have students consider how the size of shadows is related to the angle of sunlight. How might understanding this relationship help in choosing a greenhouse site?

GLAZE TESTERS

Have students contact companies and request samples of their glazing materials. Then ask students to design a series of tests to evaluate key factors for each product and make recommendations for the greenhouse. They might investigate ways to measure light passage, strength, flexibility, heat-trapping characteristics, static resistance, and so on.

EMBODIED ENERGY – FOOD FOOTPRINT

-Carefully measure amount of produce grown throughout the course of one school year
-Meter/monitor total energy consumption for one school year (this would include adding meters during installation of systems). This would also include measuring amount of any fertilizers or pest control used.
-Students measure energy input of system against energy output (calories of vegetables grown).
-Students can measure their vegetables against energy input of current vegetable supplied at school (this would require investigating where food comes from and how it is grown).

SOLAR ENERGY (PASSIVE VS. ACTIVE SYSTEMS)

-Students measure amount of solar energy entering greenhouse – how much energy is captured?
-Students experiment with thermal mass and most effective ways to capture and store solar energy.
-Students learn difference in passive systems such as thermal mass and active systems such as the solar thermal system that mechanically pumps solar heat energy into greenhouse.
-Outline the various forms that solar energy can take.

WHERE DOES FOOD COME FROM?

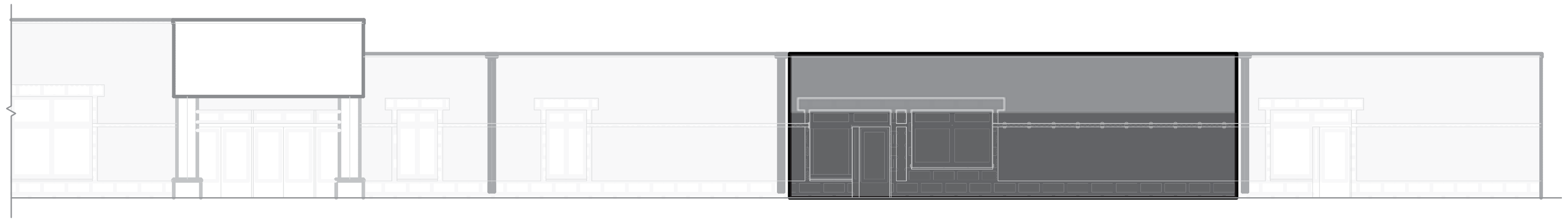
-Students trace the origin of all the food for one meal at the school (this includes all growing, packaging and processing along the way).
-Students compile number of miles food is driven, and similar to the embodied energy project, are able to convert to an estimated energy input versus energy output of food.
-Students hypothesize as to the most effective way to reduce the ecological impact of their meals.

INSTALLATION COST ESTIMATE

ITEMS	UNIT COST	TOTAL
1_GREENHOUSE SHELL		
_Acrylic 16mm paneling (4x8 sheets)	-	-
_Aluminum	-	-
_Lighting (12 grow lights)	$400	$4,800
	subtotal	**$71,000**
2_SITE PREPARATION		
_Concrete floor	tbd	tbd
_Knee wall-2 feet around building	tbd	tbd
FIRE PROTECTION		
_Fire Suppression Sprinkler system	tbd	$2,100
_Exit doors	tbd	
PLUMBING	tbd	tbd
MATERIALS		
_drip tape	15 cents/linear ft	tbd
_Benches/Tables		
_Pots (5 Gallon)	85 cents/ea	tbd
FLASHING/ROOFING to EXISITING BLDG	tbd	tbd
	subtotal	**$tbd**
3_ENERGY		
Scenario 1 - Phase 1 Solar Thermal + Exisiting Heating		$36,000-$46,500
Scenario 1 - Phase 2 Solar Thermal + Biomass Gasification		$tbd
Scenario 2 Geothermal		$30,000-$38,000
Scenario 3 Biomass Gasification		$tbd
	subtotal	**$tbd**
4_SITE SUPERVISION and COORDINATION	tbd	tbd
	subtotal	**$tbd**

APPENDIX A

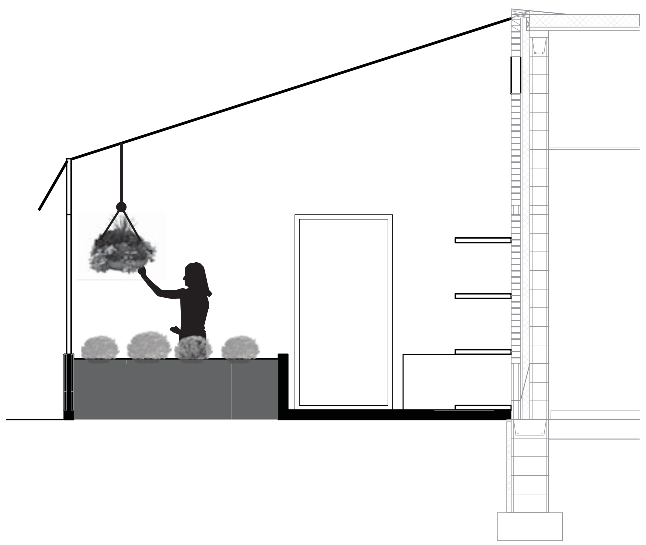
SCHEME 1: 44' LONG GREENHOUSE



South Elevation

SPECS

44' long x 16' wide
Longitudinal layout of beds with hanging baskets along perimeter
Growing space: 256 sq ft
Storage located on back wall



Profile

ENERGY
Total energy consumption _ 222 kBtu/SF/yr
Heating _ 193 kBtu/SF/yr
Lighting _ 29 kBtu/SF/yr
Average household energy consumption _ 50 kBtu/SF/yr
To increase constant temperature to 65 degrees would increase heating cost and consumption by 45%

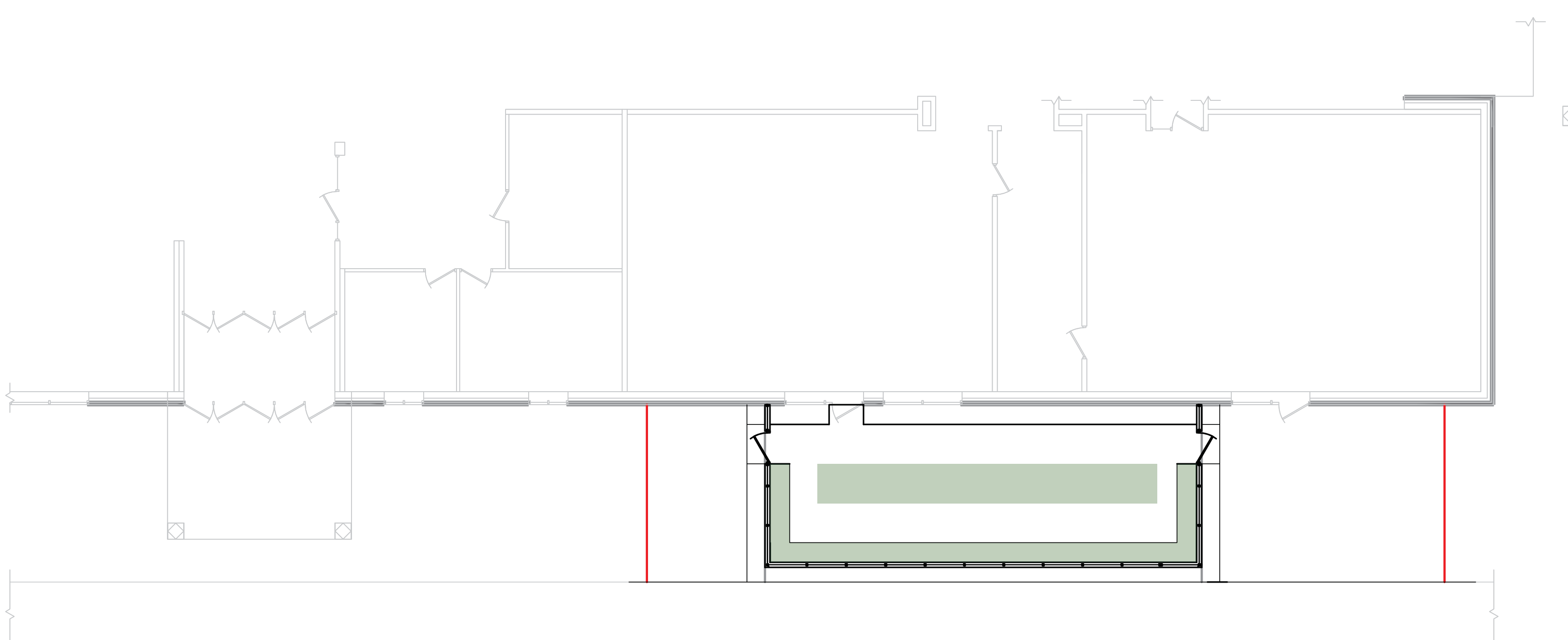
Energy Option A _
Installation costs: $13,000 - $20,000
Operational costs: $250 - $1,500

Energy Option B _
Installation costs: $30,000 - $35,000
Operational costs: approx $550
PV system to provide geothermal system with power for:

50% _ 6 kw array	100% _ 12 kw array
installation cost: $36,000	installation cost: $60,000
yearly savings: $275	yearly savings: $550

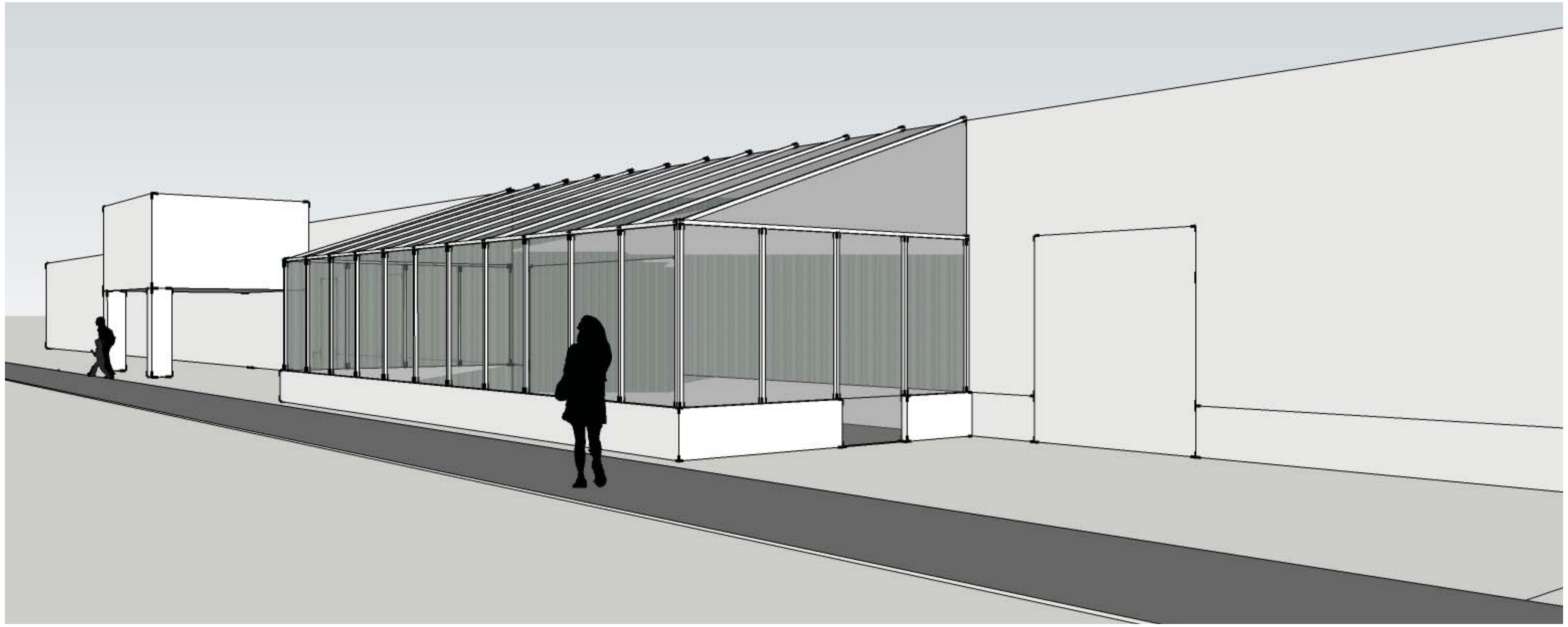
Lighting _ 6,027 kwh/yr
Total operating cost @ $.04 / kwh: $265/yr
PV system to provide lighting system with power for:

50% _ 2.5 kw array	100% _ 5 kw array
installation cost: $20,000	installation cost: $30,000
yearly savings: $132	yearly savings: $265



Plan

SCHEME 1: 44' LONG GREENHOUSE



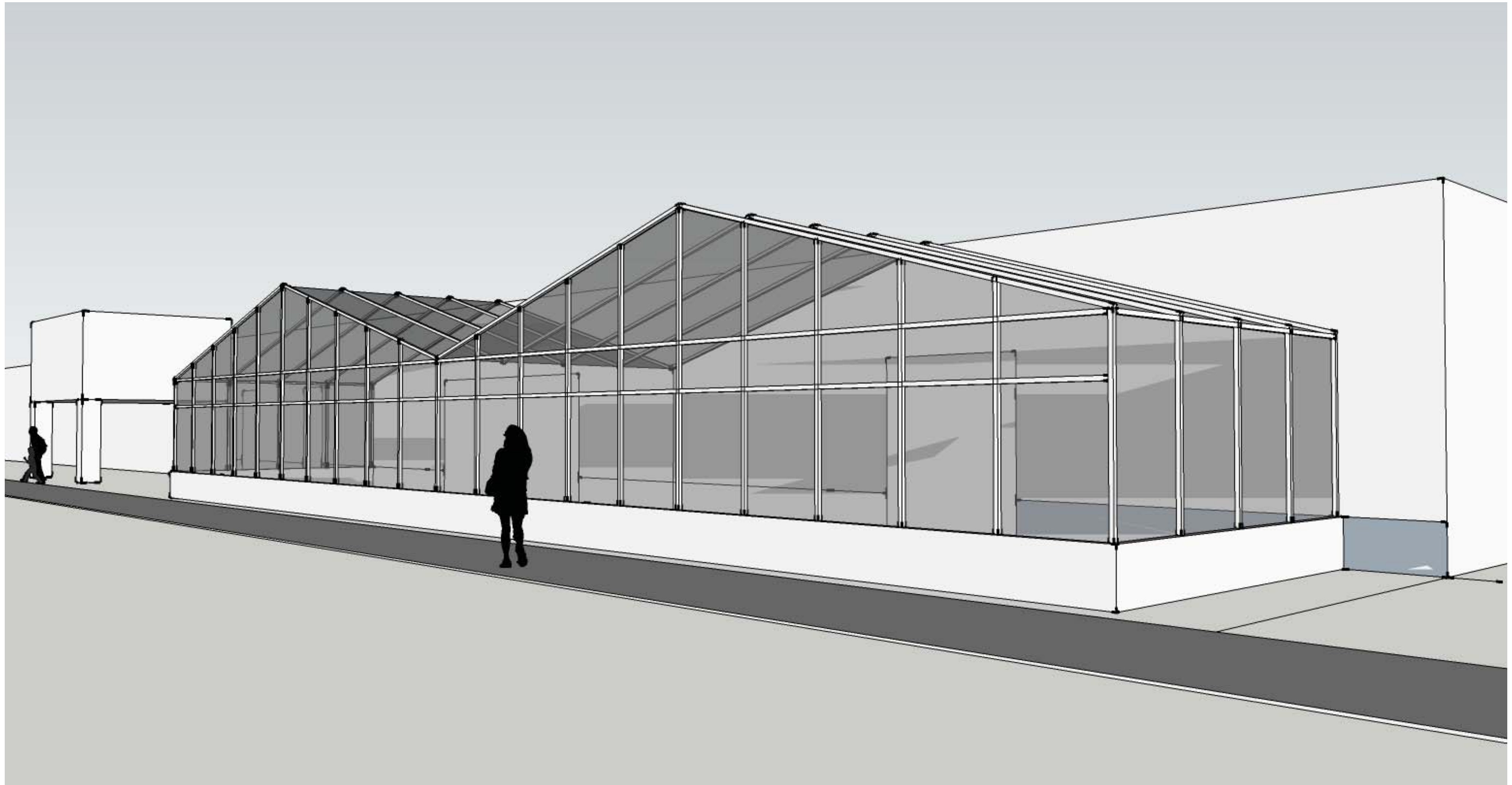
DRAFT SCHEME 1 COST ESTIMATE

ITEMS	UNIT COST	TOTAL
GREENHOUSE SHELL		
_Acrylic 16mm paneling (4x8 sheets)	-	-
_Aluminum	-	-
_Lighting (12 grow lights)	$400	$4,800
	subtotal	**$71,000**
KNEE WALL/FLOOR		
_Concrete floor	tbd	tbd
_Knee wall-2 feet around building	tbd	tbd
FIRE PROTECTION		
_Fire Suppression Sprinkler system	tbd	$2,100
_Exit doors	tbd	
PLUMBING	tbd	tbd
MATERIALS		
_drip tape	15 cents/linear ft	tbd
_Benches/Tables		
_Pots (5 Gallon)	85 cents/ea	tbd
GAS PIPING	tbd	tbd
FLASHING/ROOFING to EXISITING BLDG	tbd	tbd
ENERGY		
Energy Option A		
Installation Costs	n/a	$13,000-20,000
Operational Costs	n/a	$250-$1,500
Energy Option B		
Installation Costs	n/a	$30,000-$35,000
Operational Costs	n/a	$550
SITE SUPERVISION and COORDINATION	tbd	tbd
	***ROUGH ESTIMATED TOTAL**	**$93,100+**

***total cost reflects a high-end estimate using enegy option A**

****rough estimated total has many items yet to be determined**

SCHEME 2: 80' LONG GREENHOUSE



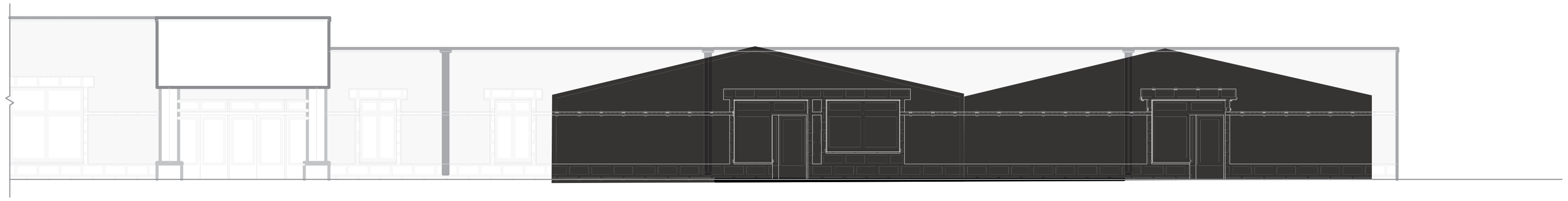
DRAFT SCHEME 2 COST ESTIMATE

LINE-ITEM COST ESTIMATE:	UNIT COST	TOTAL
GREENHOUSE SHELL		
_Acrylic 16mm paneling (4x8 sheets)	-	-
_Aluminum	-	-
_Lighting (12 grow lights)	$400	$9,600
	subtotal	**$138,000**
KNEE WALL/FLOOR		
_Concrete floor	tbd	tbd
_Knee wall-2 feet around building	tbd	tbd
FIRE PROTECTION		
_Fire Suppression Sprinkler system	tbd	$3,840
_Exit doors	tbd	
PLUMBING	tbd	tbd
MATERIALS		
_drip tape	15 cents/linear ft	tbd
_Benches/Tables		
_Pots (5 Gallon)	85 cents/ea	tbd
GAS PIPING	tbd	tbd
FLASHING/ROOFING to EXISITING BLDG	tbd	tbd
ENERGY		
Energy Option A		
Installation Costs	n/a	$13,000-20,000
Operational Costs	n/a	$500-$2,000
Energy Option B		
Installation Costs	n/a	$45,000-$50,000
Operational Costs	n/a	$950
SITE SUPERVISION and COORDINATION	tbd	tbd
	***ROUGH ESTIMATED TOTAL**	**$161,840+**

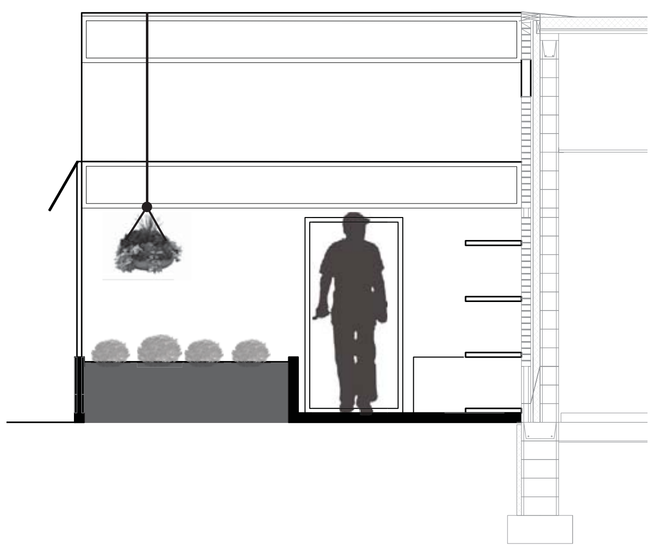
***total cost reflects a high-end estimate using enegy option A**

****rough estimated total has many items yet to be determined**

SCHEME 2: 80' LONG GREENHOUSE



South Elevation



Profile

SPECS:

80' long x 16' wide
Peninsular layout of beds (4'x10' beds) with hanging pots along edge
Growing space: 400 sq ft
Storage located on back wall

ENERGY MODEL
Total energy consumption _ 209 kBtu/SF/yr
Heating _ 177 kBtu/SF/yr
Lighting _ 32 kBtu/SF/yr
Average household energy consumption _ 50 kBtu/SF/yr
To increase constant temperature to 65 degrees would increase heating cost and consumption by 37%

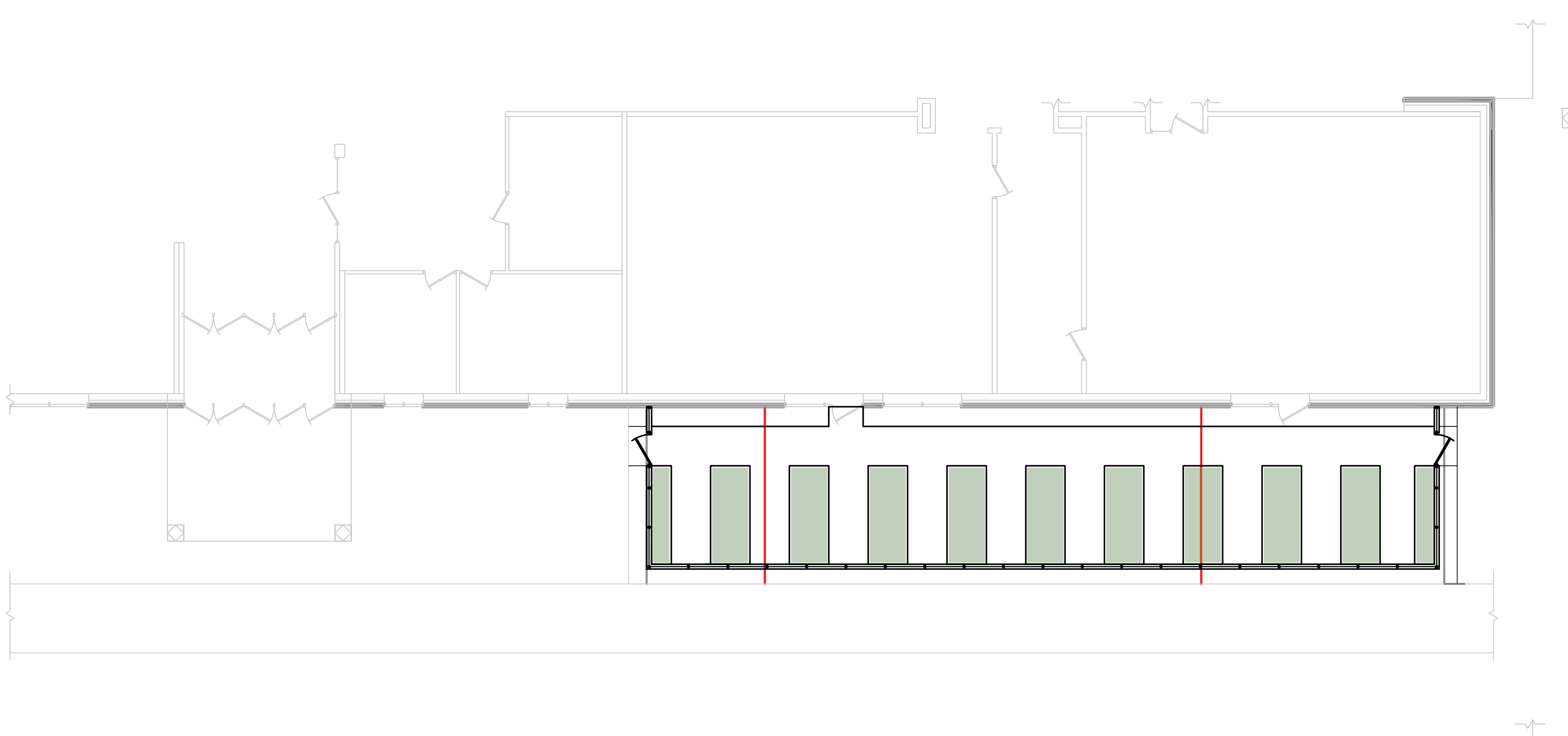
Energy Option A _
Installation costs: $13,000 - $20,000
Operational costs: $500 - $2,000

Energy Option B _
Installation costs: $45,000 - $50,000
Operational costs: approx $950

50% _ 10 kw array	100% _ 20 kw array
installation cost: $55,000	installation cost: $110,000
yearly savings: $475	yearly savings: $9,500

Lighting _ 12,052 kwh/yr
Total operating cost @ $.04 / kwh: $530/yr
PV system to provide lighting system with power for:

50% _ 5 kw array	100% _ 10 kw array
installation cost: $30,000	installation cost: $55,000
yearly savings: $265	yearly savings: $530



Plan

ENERGY MODEL

To best determine the most efficient and economical greenhouse energy solution, the first thing to note, is that to grow vegetables in the winter in our climate takes a significant amount of energy, mainly heating and lighting. A greenhouse wall will typically have an R-value of between one and three. A typical new home built today will have R-values around 21. Considering the amount of energy required to operate the greenhouse and to do so on a fixed operational budget, we looked at various energy sources. The typical approach to a greenhouse is to heat it with a small propane or natural gas heater. However, this would have been prohibitively expensive to operate. We also looked at the potential for solar-thermal heat (heating liquids with the sun and "dumping" that heat into the greenhouse). While this option had very low operating costs, the construction cost would have rivaled the cost to build the entire greenhouse, and would have been nearly impossible to use as a stand-alone system – meaning, there would need to be a back up system of some sort.

The other options we analyzed were hybrid system – meaning using more than one system to supplement the other. For example, we could use the existing system and supplement it with a small solar thermal system. The challenge with hybrid systems at the scale we would be using them is that you would be purchasing two systems, when one system would be sufficient to do the job. The most logical solutions are geothermal and "tapping" into the existing system. While the geothermal system has a relatively significant installation cost, the operational costs are quite low. With geothermal, for every unit of energy you put into it, you will get three out – essentially an efficiency of 300% (see the calculations in this report). The other option and probably the most economical both in installation and operation is using the excess capacity of the existing system to heat and ventilate the greenhouse. Essentially this option allows us to use what is already there (see the calculations in this report).

Finally, the expense of lighting can be reduced, but ultimately is critical in having a successful greenhouse. The guidelines for the lighting would be to find previously-used high-pressure sodium or metal halide lights. The lighting levels can be adjusted to meet the needs of the plants while minimizing total output and thus total energy consumption and cost.

For energy modeling purposes, greenhouse operation was assumed to start in early September and run through early May and maintain a constant temperature of 55 degrees Fahrenheit (unless noted otherwise). All options are modeled with an aluminum frame / acrylic glazing system with very little infiltration. Lighting was set at a threshold of 800 footcandles and duration of eleven hours of light per day.

Option A

Integrate heating/ventilation system into existing school heating/ventilation system

Option B

Geothermal heating and ventilation

ACKNOWLEDGEMENTS

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RESOURCES

The Northlands Winter Greenhouse Manual
By Chuck Wiebal and Carol